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A REVIEW OF ASTRONOMY IN 1914.

By R. T. Crawford.

At the close of a year in which our Society makes an award of the Bruce Gold Medal the subject for the address of the retiring President is easily fixed in that the address is a setting forth of the reasons for making the award. At this time, however, altho such an award has been made, the Directors of the Society have ordered that the *de facto* presentation of of the medal shall be made later in the year at a time when many visiting scientists will be with us on account of various meetings to be held in connection with the exposition. Our statutes require that the medal shall be awarded at the annual meeting of the Society, and that the President shall set forth the reasons for the award. This medal is awarded, as you doubtless know, "for distinguished services to astronomy." In order, therefore, to keep within the law I hereby make public announcement of the award of the Bruce Gold Medal for the year 1915 to Dr. William Wallace Campbell, Director of the Lick Observatory, and give herewith the reason for this award by stating categorically that Dr. Campbell has "rendered distinguished services to astronomy." Undoubtedly at the presentation *de facto* (probably in August next) the details of these distinguished services will be given.

Having been deprived of this subject for a retiring address I have decided to present to you a brief review of the progress and development of astronomy during the year 1914. So very much is being done continually at the many observatories and by the numerous investigators that I cannot, in an address of this kind, hope to give an exhaustive account. I shall try merely to call your attention to the most important things that have been done and to astronomical phenomena that have taken place, cautioning you at the same time that there may be some important developments that I have inadvertently overlooked.

Nineteen hundred and fourteen presented us with five comets, four of which were new or unexpected. The first was discovered by Kritzinger, March 29th; the second by Zlatinsky, May 16th; the third by NEUJMIN, June 24th; and the fourth, a naked-eye comet, independently by several observers on September 18th. It has been called Comet *e* 1914 (CAMPBELL) because this observer (at Arequipa, Peru) made the first announcement of the discovery. The fifth comet of the year (fourth in order of discovery) is Encke's Comet, which was picked up on this return by Dr. BARNARD on September 17th. This remarkable comet does not seem to have lost much if any of its brilliancy since its very first discovery. On November 16th it was reported as being of the sixth magnitude.

Of these comets, that discovered by NEUJMIN is the only one whose orbit deserves particular mention. This comet has the second largest perihelion distance (3.75 astronomical units) of any of the known comets. It is surpassed in this element by a comet of 1729, whose perihelion distance was 4.0 astronomical units. Both of these comets are moving in planes of high inclination and are probably of the same family of comets.

Definitive elements were published for two comets,. 1892 I (SWIFT) and 1898 VIII (CHASE).

The most important work concerning the Moon has been in the contributions to the theory of its motion by Professor E. W. BROWN of Yale. During the year he has presented several very valuable papers on this subject to the Royal Astronomical Society. The work on his new Tables of the Moon is nearing completion. On the observational side Professor RUSSELL of Princeton has contributed photographic determinations of the position of the Moon which give results "probably more accurate than any previous method of observation." Professor BROWN suggests a determination of the lunar parallax by a similar method.

An unusual phenomena connected with the Moon was the occultation of *Jupiter* visible on the Pacific Coast the evening of December 20th.

Steady progress was made during the year in the study of the Sun, but no epoch-making advance was made like HALE's discovery, the previous year, of the fact that the Sun is a gigantic rotating magnet. The total eclipse of August 21st was observed in Russia by a few parties. Many of the best-equipped expeditions were prevented from observing it on account of clouds.

Mercury made a transit across the disc of the Sun November 6th-7th. This was observed in many places. Besides noting the contact times, measures of the diameter of the planet were made at Greenwich.

Additions to the membership of the solar system were made as usual by the discovery of several new asteroids. Besides these a very interesting new member was discovered by Mr. NICHOLSON of the Berkeley Astronomical Department. Working with the Crossley reflector of the Lick Observatory on July 21st, he found a new moon revolving about *Jupiter.* This discovery of the Ninth Satellite of *Jupiter* marks the most important observational discovery of the year. From his own observations, using LEUSCHNER'S method, Mr. NICHOLSON computed the orbit of this new member of *Jupiter's* family. Its mean distance from the primary is 18,900,000 miles, the greatest distance from the primary of any of the satellites in the solar system. Like the Eighth Satellite, its motion is retrograde.

The most important contribution to the development of variable-star work has been the publication of the first installment of Father HAGEN'S Catalogue of Variable Stars. The accurate determination of stellar magnitudes by photo-electric photometry has continued to develop.

The work of the Astrographic Survey progressed at a satisfactory rate during the year. One of the chief difficulties in obtaining star places from photographic plates is the small number of comparison stars usually available. To overcome this Dr. SCHLESINGER has recently devised a method which is proving very efficient for cataloging stars by using a doublet of short focus, giving a good field over a large area. He finds the probable error of a position based upon four plates is less than $0''.18$. He is observing now the zone from $\delta = +2°$ to $-2° 10'$. The regions are being photographed in duplicate, the centers of one set of plates being upon the edges of others. In this way the mean of two positions of each star will depend upon fifteen comparison stars. Dr. SCHLESINGER writes: "It is hoped that this work may not only prove a valuable contribution to our knowledge of the positions and motions of faint stars, but that it may enable astronomers to decide definitely as to the advantages and disadvantages of this form of instrument for wider applications of the same kind that the future will demand."

Several interesting investigations have been made concerning the number of stars and their light. From an examination of the Harvard Plates, Dr. HENIE, of Lund, concludes that the number of stars in the sky brighter than the eleventh magnitude is 1,013,328, or about 25 per square degree. His study shows that the region poorest in stars is in *Ursa Major*, where the average is only five per square degree, and that the richest region is in *Ophiuchus*, where the average is 112 per square degree.

Dr. S. CHAPMAN contributed an article to the *Monthly Notices* "On the Total Light of the Stars." From his work he concludes that the total light is equal about to 700 first-magnitude stars; or, putting it another way, equal to 1,750 stars like *Polaris* or to 60 stars like *Sirius*. Further, he finds that "half of the stars (several hundred million) give only one-fourth per cent of the total light, an amount equal approximately to that from four second-magnitude stars."

Adding to his important work on stellar drifts, KAPTEYN finds from a thoro study of the helium stars that nearly all of these stars in a great region of the southern sky from *Argo* to *Scorpio* and *Ophiuchus* are moving together relatively to the Sun. "They all appear to be drifting to a point 5° northwest of *Vega*."

A piece of work that opens up a new field of investigation is that of Dr. COBLENTZ, of the Bureau of Standards, on the heat of the stars. Working with an apparatus he has devised, attached to the Crossley reflector of the Lick Observatory, last summer he succeeded in measuring heat radiations from stars as faint as the sixth magnitude. Among the interesting things he found is that "for the same visual brightness a yellow star sends us more heat than a white one, and a red star more than a yellow."

Of the work on the nebulæ, probably the most important contribution of the year was that made by Dr. SLIPHER in his discovery of the rotation in the Spindle Nebula in *Virgo*, N. G. C.

4594. Dr. WOLF had previously obtained evidence of rotation in the nebula M81. "These recent developments will be followed with great interest, as a study of internal motions in nebulæ must help considerably in the task of assigning to them their proper place in an ordered cosmogony."

KAPTEYN and others have heretofore shown that there is undoubted evidence of a general absorption of light in interstellar space. Recently Dr. BARNARD has brought forth convincing evidence of another kind of absorption in the investigation of the remarkable black spots in the Milky Way. He shows conclusively that such a spot is nothing else than an "opaque body in front of the star-cloud which hides part of it."

Along gravitational lines, Dr. BOTTLINGER, of Munich, presents an interesting paper on the absorption of gravitation. He attempts to show that gravitation is absorbed in traversing a medium. His opinion is that the attraction of the Sun for the Moon is enfeebled at the time of a lunar eclipse.

Probably the most valuable contribution to theoretical astronomy during the year is that of Dr. STRÖMGREN. This is an investigation of the perturbations of comets suspected of moving in hyperbolic orbits. He concludes that "there is no evidence that any comet pursues a hyperbolic path, except in so far as it has been perturbed by planets in its approach to the Sun." His researches appear to establish conclusively that the comets have their origin within the solar system. The most important part of his paper, however, is in the point that he makes and proves that in special perturbations the indirect terms due to the action of *Saturn* should always be taken into account.

In practical astronomy, the most interesting development has been in the determination of longitude thru the exchange of signals by wireless. A campaign for this purpose was carried on by the national observatories in Paris and Washington.

A new determination of the Constant of Aberration has been made by Dr. ROSS, using his photographic zenith telescope at Gaithersburg. His value is 20".495.

Advances have been made during the year in the way of large equipment. The building for the housing of the great 100-inch reflector on Mount Wilson is well under way. The mirror for the 72-inch reflector for the Canadian Government is in the course of construction by BRASHEAR. A site for the observatory to house it has been secured near Victoria, B. C. The new 20-inch refractor for the Chabot Observatory of the city of Oakland, Cal., is well on its way toward completion. Wesleyan University has been furnished with the new Van Vleck Observatory, the principal instrument of which is an 18½-inch refractor.

New Zealand has been fortunate in the gift of £50,000 by Mr. CAWTHORNE to "ensure the proper equipment and support for the new Solar Physics Observatory at Nelson." Mr. CAWTHORNE had already endowed the observatory.

In speaking of instruments it may be of interest to note that Lord ROSSE's great 6-foot telescope has recently been presented to the Science Museum at South Kensington.

In 1914 the *Nautical Almanac and American Ephemeris* for 1916 appeared. This issue marks a decided advance in this and other similar publications. With this number is inaugurated the scheme of international co-operation adopted by the congress of representatives of the various national ephemerides held in Paris in 1911.

The great war has made itself felt in various ways in astronomy. Naturally, the number of foreign publications has been materially curtailed. Many scientists of the belligerent nations have left their instruments and gone to the front. The work of the international latitude observatories has been stopped in part, and the interruption of the whole work is quite possible. The meeting of the Astronomische Gesellschaft, planned to be held August 26th-29th in Russia was of course abandoned.

An event interesting to astronomers and mathematicians occurred July 24th and a few following days, when the Napier Tercentenary Celebration was held in Edinburg. Napier's famous "Logarithmus Canonis Mirifici Descriptio" was published in 1614.

The important medal awards of the year are: The Gold Medal of the Royal Astronomical Society to Professor M. WOLF, of Heidelberg, for his work in the region of celestial photography and spectroscopy; the Gold Medal of the Royal Society to Professor E. W. BROWN, of Yale, for his work on the motion of the Moon; the Bruce Gold Medal of the Astronomical Society of the Pacific to Dr. O. BACKLUND, of Pulkowa, for his work on Encke's Comet and other investigations in theoretical astronomy; the Draper Medal of the National Academy to Professor JOEL STEBBINS, of the University of Illinois, in recognition of his work in the application of the selenium cell to celestial photometry.

Every year sees the passing of many prominent men of science and letters. Astronomy suffered severely in 1914 thru the death of two of its most eminent followers, Sir DAVID GILL and Dr. G. W. HILL, names worthy of a place along side of those of any time. In addition to these, 1914's death-roll includes the following prominent workers in astronomy: E. S. HOLDEN, the founder of this Society; R. LEHMANN-FILHÉS, C. F. PECHÜLE, N. C. DUNÉR, and WINSLOW UPTON. Sir DAVID and Dr. HILL were Bruce Gold Medallists.

In reviewing the work of the year, we find no striking discoveries as in some years, such as KAPTEYN's star streams, or CAMPBELL's that the velocities of the stars increase with their effective ages, or HALE's that the Sun is a magnet. There is to be noted, however, a very healthy, steady progress along all lines.

General View of the Ebro Observatory.

THE EBRO OBSERVATORY, TORTOSA, SPAIN.

By M. Selga, S. J.

The Ebro Observatory is located in the southern part of Cataluña, to the north of the old kingdom of Valencia, near the mouth of the Ebro River at a distance of about 20 kilometers from the sea. Situated on the edge of a small plateau which rises from the western part of the Ebro Valley some 40 meters above it, and at an altitude of 51 meters above the level of the sea, it commands a view which is a delight to the eye. To the east and south one sees in the immediate foreground the town of Roquetas, and beyond, the city of Tortosa with its architectural monuments, busy factories, olive-oil refineries, and old fortifications. The majestic Ebro River, just at the end of its course, winds thru beautiful orchards of oranges, pears, peaches and almonds. Twelve kilometers to the west are seen the arid and fantastic Caro and Espina mountains. The olive tree grows all over the small hills and endless plains. The climate is mild, rather dry, and the percentage of sunny days is high. The latitude of the observatory, determined by the Talcott method and by connection with geodetic points is $40° 49' 14''$ N.; the longitude is E. Greenwich $0^h 1^m 58^s$.

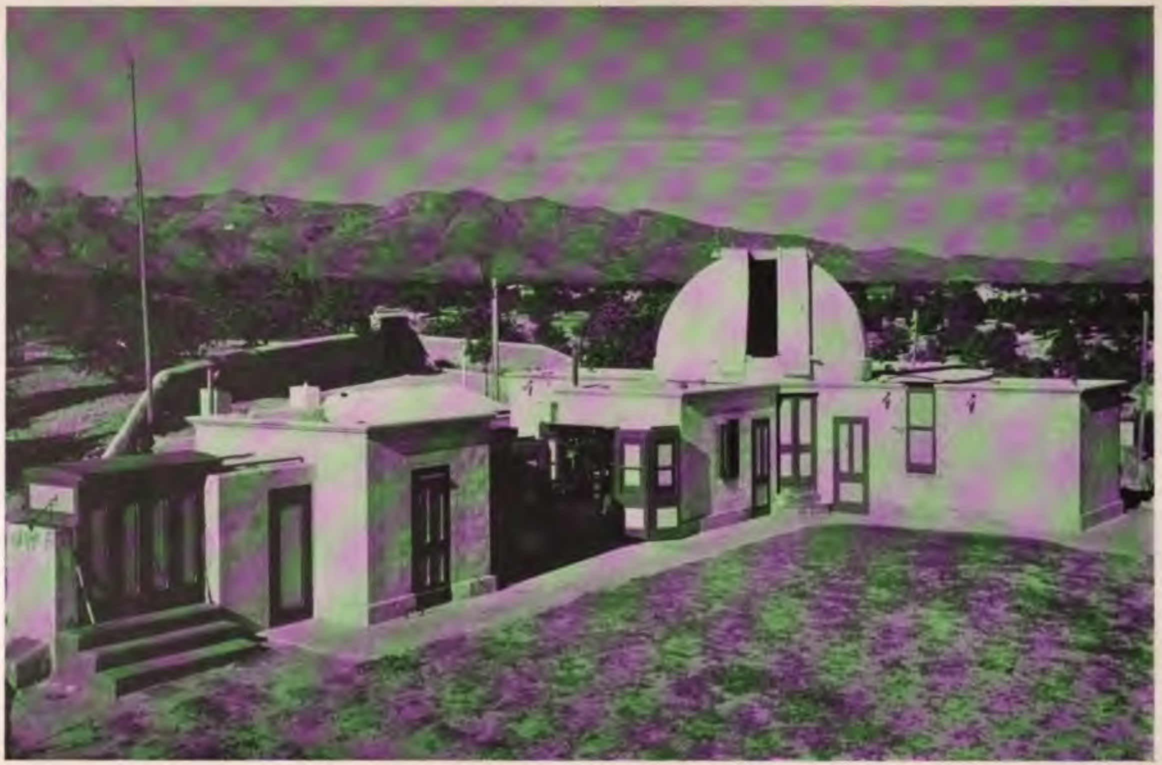
The founder and present director of the Ebro Observatory is Rev. Richard Cirera, S. J. While in charge of the magnetic department of the Manila Observatory, Manila, P. I., the advisability of obtaining simultaneous observations of solar activity and terrestrial magnetism was forcibly impressed upon his mind. His visit to the principal observatories of France, Belgium, England, Germany, Austria and Italy, and the scientific suggestions of prominent continental astronomers—Messrs. Deslandres, Evershed, Mascart, Loewy, Moureaux, Vicentini, Schwarzschild, Grablowitz and Landerer—culminated in the establishment of an astrophysical observatory at Tortosa, where the principal object is to find out the relation between solar activity and the atmospheric and magnetic variations of our planet. The observatory is of a private character and is not connected with any state college or university. The

Province of Aragon of the Society of Jesus is to be credited with the scientific triumph of having established in Tortosa a philosophical department, chemical laboratory, biological station and astrophysical observatory. Prominent business men and highly cultured citizens gave their support to the observatory: the Ebro spectroheliograph, the first of the kind to be used in Spain, is a munificent gift of Mr. GIRONA; but it is to Mr. PEDRO GIL DE MORA that the observatory looks as its greatest benefactor and quasi-founder.

The principal instruments of the observatory have been in regular use since 1905. The Tortosa observations of the solar eclipse, August 30, 1905, have proved of high value to solar research and the observatory was the observing station of several parties, from Spain and abroad, and the meeting place of prominent astronomers of France, England, United States, Germany, Belgium, Spain and Portugal. In August, 1910, the director attended the meeting of the International Union for Coöperation in Solar Research held at Mount Wilson, Pasadena, California, during the week of August 29th to September 4th. This occasion afforded him both the opportunity and the pleasure of visiting the leading observatories of the United States. The reflections on his scientific travels in Europe, as well as in America, were embodied in his book, "Viajes Científicos."

The coöperation of the observatory in every astronomical or magnetic investigation of general character has been sought by both parties of the Spanish government. Lately an appropriation was passed by both Houses to defray the expenses of the publications of the observatory. Thru the efforts of the director, an astronomical section was created in the Spanish Association for the Advancement of Science. King ALFONSO XIII himself paid a highly complimentary visit to the observatory. The technical work of the observatory and the enthusiasm of its astronomers in spreading astronomical knowledge among the people has been solemnly and officially recognized by King ALFONSO XIII in awarding in 1914 the Gran Cruz de Alfonso XII to Fr. RICHARD CIRERA.

The scientific activities of the observatory are carried on by four departments — astronomy, terrestrial magnetism, atmo-



THE SOLAR DEPARTMENT, EBRO OBSERVATORY.

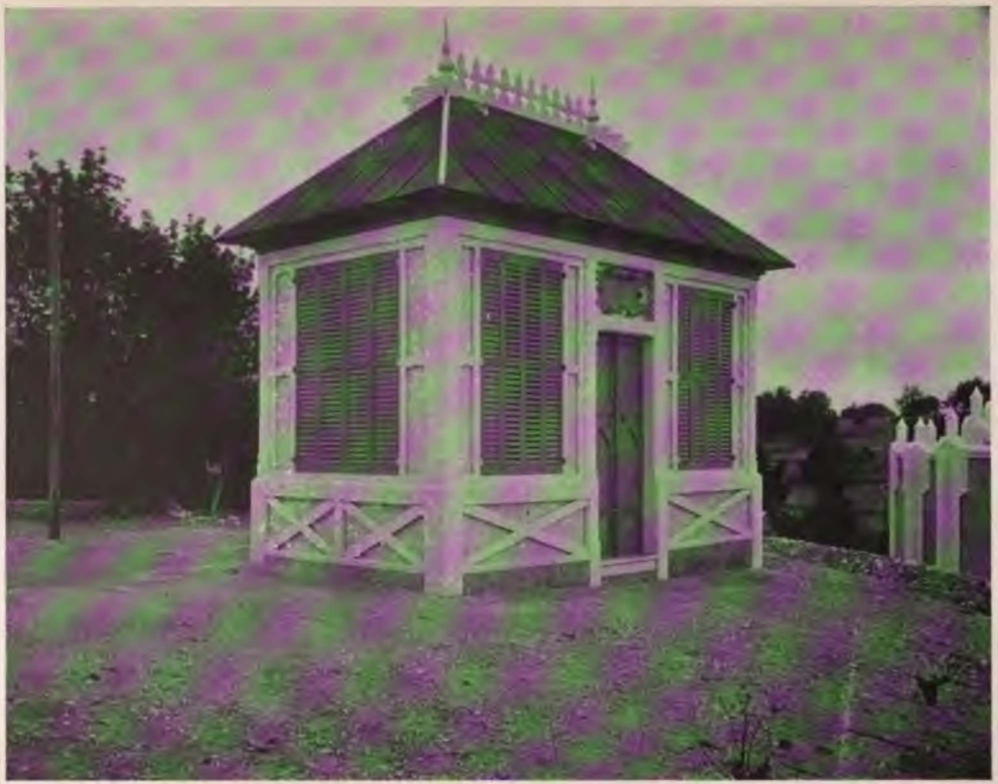
spheric electricity, and meteorology. A specialist is in charge of each department.

Astronomical Department. — Astronomical observations at Tortosa are confined solely to the Sun and the equipment is designed with this object in view. The equatorial, made by MAILLAT, of Paris, carries two objectives of 162 millimeters aperture and 2.10 meter focal length. One is corrected for the photographic rays and the other for the visual region. The right-ascension circle gives the second of time and the declination circle reads to 20″. The focal image of the Sun is about 20 millimeters in diameter. An enlarging system brings it to the standard size of 200 millimeters on the photographic plate. Photographs of the Sun are taken on every available day with the photographic equatorial. The heliographic positions of the sun-spots are deduced from the plate, either by the method used at Greenwich, by means of the position micrometer or by different graphs. The measured surface of the sun-spots is read in square millimeters and tenths of a square millimeter, and the reduced surface is computed to millionths of the solar hemisphere. Flocculi or calcium vapors in the Sun's cromosphere are studied by means of an Evershed spectroheliograph. An excellent spectrogoniometer of four prisms, in connection with a coelostat affords an opportunity of determining the radial velocities of different vapors of the solar atmosphere. The importance of solar radiation work to determine the solar constant was early recognized and fully realized by the director. Observations have been carried on daily with an Ångstrom compensating pyrheliometer.

Magnetic Department.—The magnetic observations consist in the determination of absolute values of the intensity and direction of the Earth's magnetic field and of the variation of its intensity. The absolute measures are taken in a pavilion very favorably located. There is not a single trolley line connecting the busy Tortosa with Roquetas and Arrabal del Jesús, and this is a great blessing the observatory people are to be thankful for. The industrial electric currents rendered worthless the magnetic observations of the magnetic observatory of Parc Saint Maur, near Paris. The magnetic observatories of Greenwich, Kiev, Perpignan, Nice, Lyons and Manila either had to be transferred to a safer place or had to be abandoned or greatly modified. Again magnetic iron is highly detrimental to absolute magnetic measures. A careful geologic and petrographic study of the region surrounding the observatory was made before the site of the magnetic pavilion was chosen. Wood was the only material of construction: the locks, latches, hinges, keys, screws, every metallic piece is of copper; the supporting piers are of stone and marble. Since the distance between the absolute measures pavilion and the variation pavilion is only 14 meters, the magnetic field can be taken to be the same for both observing houses. Wood, local stone, copper and zinc were used for construction; every material was tested by the Dover magnetometer before it was admitted and used. The thermographs show practically no variation of temperature in the inclosed piers.

It will be well to recall to our minds that the seven magnetic elements are: the declination, the inclination, the horizontal component, the vertical component, the total intensity, the north geographic component and the east component. Out of these seven elements, the three which are most easily determined by absolute measures are the declination, the horizontal component and the inclination. The Ebro Observatory is provided with a Dover unifilar magnetometer, Kiew type, whose constants were determined at the National Physical Laboratory of England, to measure the declination and the horizontal component. A Schulze terrestrial inductor, Potsdam type, measures the inclination, to a tenth of a minute of arc. In the variation pavilion the declination is measured by a declinometer, the horizontal component by a bifilar and the vertical component by a magnetic balance, all of Mascart type.

The excellent location of the observatory and the efficiency of its apparatus caused the Spanish Government to request the director that the Ebro Observatory be made a central magnetic station in the construction of the magnetic chart of Spain. It is intended to combine the magnetic observations of Tortosa with those already made at San Fernando and Lisbon. It is expected that the comparison of the magnetic observations of Val Joyeux, near Paris, with those of Tortosa will eventually lead to the value of the secular variation corresponding to the south of France.



Pavilion for Absolute Magnetic Measures, Ebro Observatory.

Electro-Meteorologic Department. — It is needless to say that Fortin and Tonnelot barometers, maximum and minimum thermometers, Arago actinometer, sunshine recorder, Cornu photopolarimeter, Besson nephoscope, Richard barographs, thermographs, anemographs, and hydrographs are the apparatus used for the daily or weekly record of the atmospheric variations and for the local forecast of the weather.

In the electric section, the ions, the atmospheric potential, Herzt waves and telluric currents are the object of investigation. The study of atmospheric ions can be accomplished by finding either relative values that give a vague idea of the ionization of the air or absolute values of the conductivity and of its elements. We know the relative values from the determination of the coefficient of electric dispersion by means of an Elster and Geitel apparatus. The number of ions and the absolute conductivity of the air is computed from the data obtained from a Gerdien apparatus of the early type. A registering apparatus in connection with a Thompson-Chauvenau collector and two Thompson-Mascart quadrant electrometers of different sensibility record the variations of atmospheric potential. Absolute measures of atmospheric potential are made at an isolated station, at some distance from the observatory, in order to be free from the effect of local perturbations produced by buildings and surrounding trees.

It is well known that when we have an electrical disturbance in the atmosphere, this disturbance is the source of electromagnetic waves similar to those produced in wireless telegraphy. These waves may be detected and recorded by a special apparatus similar to that used as a receiver for ordinary waves of wireless telegraphy. This instrument is known as a ceraunograph. The Tortosa ceraunograph gives a continuous record of electric storms occurring in the neighborhood or within a certain distance from the Ebro Valley.

Besides artificial electric waves excited by the trolley cars, motors and electric plants of our industrial cities, there are natural electric waves moving along the crust of the Earth. Sometimes they have cut off telegraphic communication; at other times, as in 1859, between Portland and Boston, the difference of potential of the telluric currents between the terminals of the line has been such that telegraphic messages could be sent thru. For the observation of telluric currents, the Ebro Observatory runs a 1,420-meter line, west-east, to el Colegio Máximo and another, north-south, to a point 1,280 meters distant from the observatory; the angle between the two lines is 87° 21′ towards the east. The entrance wires are joined to two Despretz and D'Arsonval galvanometers and the deviations are recorded on the photographic registering apparatus. The seismological equipment consists of a Vicentini seismograph and two Grablowitz pendulums.

Publications.—Four Memoirs have been published by the observatory staff. In the first the observatory was introduced to the astronomical world, its instruments described, its program outlined, and the results of its observations of the solar eclipse, August 30, 1905, made public. In the second, Rev. MARIANO BALCELLS, S. J., gives a detailed description of the astronomical instruments of the solar department and outlines the problems of solar research. The author had come to America to work under the direction of the inventor of the spectroheliograph and was taking several courses in the Massachusetts Institute of Technology when his life was untimely cut off. E. MERVEILLE, S. J., and J. GARCÍA MOLLÁ, S. J., are credited with the description of the instruments and exposition of the problems of the magnetic and electric departments.

Since 1910, the observatory issues a regular monthly bulletin, printed in two languages, Spanish and French. It gives the numerical data of observation in heliophysics, meteorology and geophysics. For a comparison of the results obtained in these three departments of research, these data are plotted in diagrams on which days and fractions of a day are taken as abscissae and the values in the proper unit of the particular element under consideration as ordinates.

These charts exhibit then, on the same page, for each hour of the day, the number, position and area of sun-spots and flocculi; the hours of sunshine and of clouds, the atmospheric pressure, humidity, temperature, direction and velocity of the wind, atmospheric potential and telluric currents; the magnetic intensity and declination, and, finally, the occurrence and intensity of seismic phenomena.

Iberica.—What the *Scientific American* is for the American, *Cosmos* for the Frenchman, *Nature* for the Englishman, that is *Iberica* for the Spaniard. The necessity of a weekly scientific magazine, well illustrated and with up-to-date articles was long felt by Spanish-speaking people. That *Iberica* supplies this need is plainly shown by the fact that two months after its appearance the copies of *Iberica* were spread all over the provinces of Spain and the different South American republics. I have seen *Iberica* on the shelves of the great libraries of Boston, New York and San Francisco, as well as in the private libraries of distinguished scientific men of this country.

MT. HAMILTON, January 20, 1915.

PERIODIC VARIATION IN THE POSITION OF THE MIRE IN 1914.

By R. H. TUCKER.

The position of the Mire with reference to the true meridian has been derived from the meridian-circle observations of the past year. Evidence of change in its position was apparent in the current reductions for clock errors, made usually once a week, and at the close of the year the definite computations of the azimuth furnish material for the complete comparison of positions.

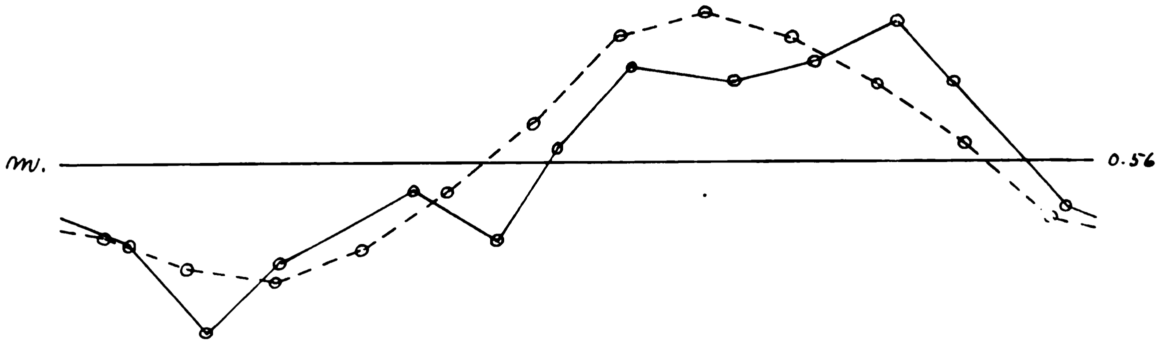
It is necessary to consider all the sources of possible systematic error, in order that these shall be eliminated from the results. Systematic errors in the right ascensions of the circumpolar stars, employed for the determination of the azimuth of the meridian circle, might be suspected of producing apparent periodic changes in the position of the Mire. A very complete discussion of the determinations of the Mire was published in the *Lick Observatory Bulletin*, No. 213, in the year 1912. That discussion was based, primarily, on the observations of *Polaris*, during the fundamental work of the years 1905 to 1908, and the results were accordingly unaffected by systematic errors of right ascension. The results of the meridian-circle observations, previous to the beginning of the fundamental work, were also tabulated, as well as the general trend of the changes up to the year 1912. The fundamental work showed a distinct annual periodic term, a daily periodic term, and a secular change which seemed to have been continuous from 1904 to 1912. The observations of the eleven years, from 1893 to 1904, gave a well-determined annual term of the form, $-0^s.060 \sin \Delta\alpha$, where $\Delta\alpha$ was reckoned from the first of December; and the application of this term reduced the average residuals per month from $0^s.029$ to $0^s.006$, which is distinct evidence of the faithfulness of the term in reproducing the variation. Since 1912 the secular change appears to have ceased, and there was only slight indication of such change previous to 1904. In those eight years, the total amount was nearly $0^s.4$ or about 6″. At the distance of the meridian mark from the instrument, a change of 2″ corresponds to about a hundredth of an inch. The tiny hole in the metal disc, which gives an illuminated circle for the meridian mark, lies to the west of true south, and is about 12″ in diameter. The movement is toward the east in winter, reaching a minimum distance in March and a maximum in late summer. In the discussion of its position, given in the published *Bulletin*, the systematic observations of *Polaris*, and the continued series of the early night observations unite in confirming the annual term, while the daily periodic term is only evident in the observations of *Polaris,* which were made at every hour of the day and night. In the present series for 1914, the determinations were generally included between 8 P. M. and midnight, tho some were made an hour or two outside these limits.

The following tabulation of ΔM is made up by combining the means of eight consecutive nights, which constitute a program containing the same fundamental stars, with the monthly means. The programs give somewhat unequal distribution in the year, owing to the bad weather of January, April and December, while the monthly means have considerable variety of weights, from April with two nights, to July and November with thirteen each. The combination gives a better distribution of the same material. The values tabulated, with the respective dates, have been plotted, to give a graphical illustration of the periodic variation. The values have not been smoothed out into curves; but the more regular one, in broken lines, can be easily distinguished as that of the periodic term from eleven years.

Date	Mean ΔM	Reduced ΔM	v.
Jan. 25	0^s.521	0^s.569	+^{s}.012
Feb. 21	.481	.540	—.017
Mar. 17	.513	.570	+.013
May 3	.546	.573	+.016
June 1	.522	.522	—.035
June 23	.565	.542	—.015
July 20	.601	.555	—.002
Aug. 27	.596	.536	—.021
Sept. 24	.605	.550	—.007
Oct. 23	.623	.587	+.030
Nov. 11	.597	.578	+.021
Dec. 21	.539	.559	+.002
Mean.	—0^s.559	0^s.557	
v.	± 0 .039		± 0^s.016

The probable errors of determination give some indication of the real nature of the variation. The determination of the position of the Mire is practically free from any effect depending upon instrumental errors, and variations of these errors. The azimuth has been determined from two pairs of circumpolar stars each night, near the beginning and the close of observations, with an interval of approximately three hours; and the reading on the Mire has usually been taken very close to the epoch of each pair of circumpolars. The change in the position of the Mire each night can then be compared with the change in the azimuth of the instrument, and in general these changes confirm each other, allowing for errors of observation.

The probable error of a single determination of the Mire is quite exactly ± 0^s.010, as found from the comparison of the two values of each night. This includes the error of reading on the Mire, and the error of azimuth from the two pairs of circumpolar stars; and the effect of changes in the position of Mire and instrument augments this probable error, when the changes do not agree in direction and amount.



Plot of ΔM, 1914; and Eleven-Year Annual Periodic Term.

The azimuth is the noticeably variable correction to the meridian-circle observations. It has been found to have a range in the past year of $0^s.63$, which is $9''.5$. On three quarters of the nights of this period, the progressive variation is large enuf to include a rate of change in the azimuth correction, at least $0^s.02$ in the three hours. The changes from day to day in the azimuth correction do not appear to follow any law, and those between adjoining dates of observation are often comparatively large. The direction of the change is more often negative than positive, for the hours employed in this series, in the proportion of two to one; while of the changes in excess of $0^s.02$, the proportion of negative to positive is three to one. This is an indication of a daily term in the variation of the azimuth of the instrument. The change during a night does not give any indication of the value found for the night succeeding, and there is no evidence of progressive changes in azimuth.

To follow up the probable error results, from the combination of values of ΔM in groups of four nights, when the same pairs of circumpolar stars were used, and the instrument was in the same position, the p. e. of a single night is found to be $\pm 0^s.018$. This is double the value which would result from accidental error of observation, and is thus an indication that the position of the Mire changes from night to night.

As a further check upon systematic errors due to the right ascensions of the circumpolar stars, if the probable error of a group of four nights is determined from the comparison of sets of four nights clamp east and four nights clamp west, with the same pairs of circumpolars, this is found to be $\pm 0^s.027$. Taking successive groups of four nights in the same position of the instrument, but with different pairs of circumpolar stars, with approximately two hours' interval between, the probable error of a group of four is $\pm 0^s.015$. This is not only an indication that the systematic errors of right ascension are not of importance, but would seem to indicate that some residual error is due to the reversal of position, possibly to error in the adopted values of the collimation. The size of the probable errors of the groups, when compared with those of single nights, also indicates change in the position of the meridian mark. The probable error of a group of four nights, derived from a mean value of the meridian mark for the year, is ± $0^s.037$, which indicates again the existence of changes in position, aside from the errors of determination.

If we adopt the periodic term in the change of position, given by the eleven-year period, 1893 to 1904, the probable error of a group of four is reduced to ± $0^s.024$, two thirds of the p. e. without the application of the periodic term correction.

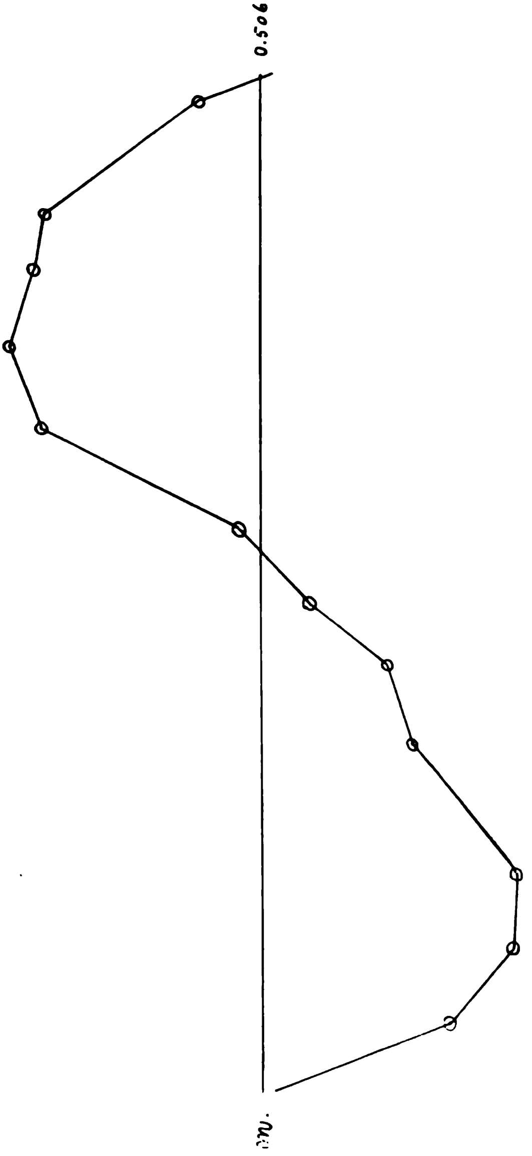
In the plot of the different determinations of the Mire position, the curve approximates very closely the sine curve given by the expression derived from the eleven-year continuous period. It would not follow a temperature curve for the year, since the maximum and minimum points occur near the equinoxes. The total range of ΔM is $3''.6$, from the extreme daily measures; the groups of four nights give a range of $3''.0$; while the programs of eight nights, averaging a month each, have a range of $2''.0$, equivalent to one hundredth of an inch. The formula for the periodic variation of the monthly values has an amplitude of $0^s.12$, or $1''.8$.

In the probable error tests of the original results, the fact that the computed probable error is much smaller than the average of the residuals indicates that these latter do not follow the law of accidental error, they being actually nearly uniform in size, with none exceeding twice the average. In the discussion of the values corrected for periodic variation, the individual residuals conform better to the law of accidental error, and single residuals equal three times the probable error, while the relation between average residual and probable error is closely that given by the theory of accidental errors. Tests by probable error can easily be misinterpreted, and conclusions in regard to the precision of observations can be drawn that are far from valid; but the proper use of the tests can often give us direct testimony of the existence of systematic error, and of the actual precision of results. The small size of the accidental error of determination of the position of the Mire from observations of different pairs of circumpolar stars on the same night, and the fact that errors of groups, with different pairs, are smaller than the errors of groups derived from the same pairs including reversal of the instrument, all tend to disprove the effect of any serious systematic errors in the right ascensions of the circumpolar stars used for azimuth.

The effect of the collimation correction needs to be considered. This has been larger during the past year than usual. But the average values of ΔM from the two positions of the instrument are exactly the same, with the same weight for each. There are twenty-four determinations of the collimation, made generally at reversal of the instrument, by the use of both collimators. The mean value of c is the same in each position, $-0^s.023$ clamp west, and $-0^s.023$ clamp east. There would thus be a maximum mean effect of $0^s.046$, nearly $7''$, between determinations of ΔM in the two positions of the meridian circle. If the collimation should be assumed to be constant during the entire year, the probable error of a single determination of c would be $\pm 0^s.012$. But the variations were evident, and in general a value of the correction was adopted from the mean of two successive measures. The adopted values range from $0^s.000$ to $0^s.042$. If the collimation is assumed to be the same in the two positions, before and after reversal, the probable error of a single determination of c is $\pm 0^s.006$. No dependence upon temperature can be traced in the measures of collimation, the range of determinations being $44°$ to $82°$ Fahrenheit.

There remains the level correction to be considered. This has been found to vary but very slightly during a night, and to have but small changes between successive nights. There has been, however, during the past year, a well-defined curve of variation, which can be expressed in the form, $-0^s.12 \sin \Delta t$, where Δt is reckoned from the first of January. The east end of the axis rises in late winter, and then falls to its lowest point thru spring and summer, to rise again in the late autumn. As this curve has maximum and minimum at points near the equinoxes, it does not correspond to a sine curve of annual temperature, tho this might be accounted for by a lag in the variation of the instrumental level.

The level correction has been tabulated here, in precisely the same manner as in the tabulation of ΔM preceding. The reduced values of the correction are obtained by the application



Plot of Level Variation in 1914.

of corrections for the periodic term, $-0^{s}.12 \sin \Delta t$, which is derived from the observations of this year. It will be remembered that the periodic term of ΔM was derived from observations made in the years 1893 to 1904, and applied to the observations of the current year:—

Mean Date	b	Reduced b	v.
Jan. 25	$-0^{s}.592$	$-0^{s}.543$	$-0^{s}.033$
Feb. 21	.621	.527	$-.017$
Mar. 17	.625	.508	$+.002$
May 3	.575	.472	$+.038$
June 1	.564	.506	$+.004$
June 23	.528	.514	$-.004$
July 20	.496	.537	$-.027$
Aug. 27	.403	.504	$+.006$
Sept. 24	.389	.508	$+.002$
Oct. 22	.400	.512	$-.002$
Nov. 11	.404	.494	$+.016$
Dec. 21	.477	.500	$+.010$
Mean.	$-0^{s}.506$	$-0^{s}.510$	
v.	$\pm 0\ .078$		$\pm 0^{s}.013$

In the mean values, April is not represented, and June has two values, as in the combinations of ΔM.

The probable error of a level determination, assuming that the level remains constant during the period of observation for every night, is found to be $\pm 0^{s}.006$. In the groups of four nights the probable error of a single night is $\pm 0^{s}.012$, indicating slight changes of level from night to night.

The total range of level correction is $0^{s}.33$, but the means of eight nights in a program have a range of $0^{s}.24$, or $3''.6$, the same amount as the amplitude of the computed periodic variation. A constant level correction has been adopted on each night.

The average difference between successive groups of four nights, in the two opposite positions of the meridian circle, is rather larger than the average difference between successive groups in the same position, indicating that some small part of the change in the level correction may be due to changed conditions at reversal, or to residual errors in the determination of the collimation correction.

To recapitulate: it must be plainly stated that the position of the Mire is referred to the true meridian, and it is determined independently of the actual changes in the meridian circle itself, except for the effect of such residual errors as may exist in the determination of the instrumental corrections. The observed range in the position of the Mire amounts to $0^s.24$, in the daily values. The monthly averages cover about half that range, and are well represented by a periodic sine term of the corresponding amplitude. The collimation correction of $0^s.023$, on the average, does not affect the determination, as the same mean value of the meridian mark is derived in both positions of the instrument. The level correction changes slowly, and has, during the year, a periodic variation expressed by a sine term of $0^s.24$ amplitude.

Confirmatory evidence of the freedom from the effect of any systematic errors in the right ascensions of the circumpolar stars is strong. If the periodic changes in the position of the meridian mark are due to a twist in the mountain, this might be expected to show in the azimuths of the meridian circle; but if so, the changes of azimuth are masked by the accidental variations, which are comparatively large. No material is here available for the discussion of a. daily period. The secular change, which was plainly evident from 1904 to 1912, has ceased, and the mean values of the last three years have been approximately the same.

The similarity of the curves which represent the changes in the position of the meridian mark, and the change in the level of the instrument, during the year, must be evident. The same cause may operate in both cases, producing effects which are not dependent upon each other. A twist in the mountain, operating thru the year, may be accompanied by a tilt at the summit, which would be reproduced in a corresponding change in the level of the piers of the meridian circle. The reduction in the size of the average residuals is evidence of the real nature of the variation in both cases.

In this discussion one hundred nights of observation have been included, extending into January, 1915, with two nights.

The Mire can always be used as a check upon the azimuth, during short periods of time; and it is always useful for the necessary check upon computations. Many of the corrections to the instrument, which enter as corrections to the original results of observation, are largely eliminated in the computed places of the stars, since the right ascensions of the fundamental stars are adopted as standard, but the discussion of every source of error has its real value.

Lick Observatory, January 20, 1915.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1915.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon ...	Mar. 1, 10^{h} 33^{m} A.M.	Last Quarter..	Apr. 6, 12^{h} 12^{m} P.M.
Last Quarter..	" 8, 4 28 A.M.	New Moon....	" 14, 3 36 A.M.
New Moon....	" 15, 11 42 A.M.	First Quarter..	" 22, 7 39 A.M.
First Quarter.	" 23, 2 48 P.M.	Full Moon....	" 29, 6 19 A.M.
Full Moon....	" 30, 9 38 P.M.		

The Vernal Equinox, the time when the Sun crosses the celestial equator from south to north and enters the sign (not the constellation) *Aries*, occurs on March 21st about 9 A. M. Pacific time.

Five of the planets, *Mercury*, *Venus*, *Mars*, *Jupiter* and *Uranus* are morning objects, but not all are far enuf away from the Sun for naked-eye observation. Their motions are apparently quite complicated.

Mercury passed inferior conjunction with the Sun on February 21st, and by March 1st rises not quite an hour before sunrise. Its apparent distance from the Sun increases until the morning of March 20th, when it reaches greatest west elongation 27° 44′. It then rises a little more than an hour before sunrise. The distance from the Sun then begins to grow smaller so that by the end of the month the interval between the rising of the Sun and of the planet is somewhat less than an hour. The interval during April grows continuously smaller, and superior conjunction is reached on May 1st. Thus the conditions for visibility are not very good, as the planet is not easily seen to naked-eye view when the interval is less than one hour; but for a few days about the time of greatest elongation it may be seen low down in the morning twilight, rising nearly 15° south of the sunrise point. This position, south of the Sun, is the cause of the small interval between the planet's rising and sunrise, as the apparent distance from Sun to planet is about 50 per cent greater than it was at the greatest east elongation in early February, when the planet remained above the horizon for nearly an hour and a half after sunset. *Mercury* is in conjunction with *Mars* on February 28th, with the Moon on March 13th, with *Jupiter* on March 29th, and with *Mars* on April 3d.

Venus is also a morning object, rising 2^h 20^m before sunrise on March 1st, and the interval diminishes steadily, so that by the end of April it is only 1^h 18^m; but the great brightness of the planet makes it a conspicuous object thruout the period, altho the planet has lost much of its brilliance since early January. It is in conjunction with *Uranus* on the night of March 18th, and a very interesting conjunction with *Jupiter* will occur on the morning of April 15th. At the time of nearest approach the apparent distance between the planets will be only 0° 9′, less than one third of the apparent diameter of the Moon. This nearest approach occurs about 8 A. M. P. S. T., some time after sunrise in the United States.

Mars is also a morning star, gradually moving farther away from the Sun. On March 1st it rises 0^h 37^m before sunrise and at the end of April a little more than one hour before, so that it is gradually getting into position for naked-eye view. Its conjunctions with *Mercury* and *Venus* have already been mentioned. There is also a very close conjunction with *Jupiter* on the evening of March 23d, both planets being below our horizon at the time, the least distance between the planets being only 0° 12′; but on the mornings before and after they will be quite close together. *Mars* passes to the south of *Jupiter*, with relative motion from west toward east. *Mars* is beginning to brighten up perceptibly, being at the end of April 50 per cent brighter than it was when at its greatest distance from the Earth in November, 1914. In April it will be brighter than the Pole star. Its distance from the Earth during that month is a little more than two hundred million miles.

Jupiter passed conjunction with the Sun on the morning of February 24th and on March 1st rises only 6 minutes before sunrise, but the apparent distance between the bodies increases somewhat rapidly, so that on April 1st it rises about an hour before sunrise and at the end of the month nearly two hours before. Its great brightness makes it an easy naked-eye object in the morning twilight some time before the end of March. Its conjunctions with other planets have been previously mentioned.

Saturn is in fine position for evening observation, remaining above the horizon until about half-after two on March 1st and about half-after ten on April 30th. It moves rather slowly, about 4°, eastward in the border region between *Taurus* and *Gemini*, a few degrees south and east of *β Tauri*. As seen in the telescope, the minor axis of the rings is about 45 per cent of the major axis; so the rings are nearly at their maximum breadth.

Uranus is a morning star, rising on March 1st a little more than an hour before sunrise, and this interval increases rapidly, so that by the end of April it rises before two o'clock. However, the planet is so faint, only about sixth magnitude, that it is a difficult naked-eye object when it is less than two hours above the horizon. It is in the eastern part of the constellation *Capricorn* and moves about 2° eastward and northward during the two months.

Neptune is in good position for evening observation, but being only eighth magnitude it is too faint to be seen without a telescope. It is in the constellation *Cancer*, and passes the meridian somewhat south of the zenith at 9:26 P. M. on March 1st and at about 5:30 on April 30th.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Note on the Color of the Faint Stars in the Orion Nebula.

A series of comparisons of the magnitudes of the stars in the *Orion* nebula with those of the North Polar Sequence has been made with the 60-inch reflector in order to determine the relative color of the bright and faint stars. Provisional photographic and photovisual magnitudes have thus been secured for nearly a hundred stars in and near the central part of the nebula. The exposures on the two kinds of plates were made in close succession so as to avoid errors due to the possible magnitude changes of the many known and suspected variables. Diaphrams were used to reduce the magnitudes of the brighter stars sufficiently for direct comparison with the fainter ones in the same field. For nine stars whose magnitudes are between 6 and 9 and whose spectra are between B8 and A2, the average color index was found to be + 0.04 mag. For 33 stars for which the photographic magnitude is between 11 and 16, the average color index is + 0.68 magnitude. Of these 33 faint stars, only six have color indices less than half a magnitude. Only two have negative values, and for both of these the magnitudes are of low weight because of considerable distance from the center of the plate. Most of the faint stars so far investigated are in the thinner parts of the nebula between θ_1 *Orionis* and c *Orionis*. As yet there is no indication, however, that the color indices are greater or less in the denser nebulosity.

The large value of the color index suggests either that these faint stars are of redder spectral type (solar type on the average) or that an abnormal space absorption is present, or that both these factors affect the colors. There is the possibility also of a color effect from absolute luminosity, but if such be the case it must be in the opposite direction from that found by ADAMS. If absorption is the chief cause, then, since the color index of the nine bright stars investigated is normal for spectral type A, the faint stars must be much more distant than the brighter ones, and therefore probably not connected with the predominating group of bright *Orion* stars in this region. It seems more likely, however, that there is no conspicuous absorption peculiar to the nebula itself, and that the colors of the faint stars are to be accounted for in the same way as redness of faint stars in other parts of the sky. In any case there seems to be no definite evidence for associating the fainter stars in this vicinity with the *Orion* nebula. The average redness found for these stars is slightly less than that found by SEARES for stars of the same magnitudes near the north pole. The galactic latitude of the latter region is ten degrees greater.

HARLOW SHAPLEY.

MOUNT WILSON SOLAR OBSERVATORY, January, 1915.

THE MARTIN KELLOGG FELLOWSHIP.

Mr. C. E. ADAMS (M. S., University of New Zealand), Government Astronomer of New Zealand, has been appointed Martin Kellogg Fellow in the Lick Observatory. Mr. ADAMS has been granted leave of absence by his government, and will spend his time at Mount Hamilton and engage principally in astrophysical studies.

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

A CHINESE STAR CATALOG.

About the same time that BRADLEY was working out his system of star positions, with the accurate methods and refined mural quadrant of the Greenwich Observatory, three European Jesuit missionaries in China and a few Chinese men of science were engaged in the construction of astronomical instruments and were endeavoring to define the limits of, and to count the number of, stars in each constellation.[1] The description of a huge armillary sphere and the memoirs relating to the star observations were embodied in the Chinese book, *K‘in-ting-i-siang-k‘ao-tch‘eng*, which, in plain English, means instruments made by order of the emperor. Out of the five catalogs contained in the book, the first is an abridged catalog, in which the stars are divided into the classical Chinese 3 *yuen* and 28 *sicou;* the second and third are complete catalogs, the difference being the arrangement of stars according to longitude in the second and according to right ascension in the third; the fourth is a catalog of stars less than 10° from the ecliptic, subject to occultation by the Moon and planets; the fifth is a catalog of galactic stars. It is to the Observatory of Zo-Sè, China, founded and supervised by the French Jesuit Mission of China, that we owe the publication of these abridged and complete star catalogs, and astronomers are indebted to Rev. P. TSUTSIHASHI, S. J., for the reduction of the stars of the catalog to the epoch of 1875.0 and for the revision of the Chinese catalog.[2]

Complete Catalog.—In the complete catalog, the stars are arranged in order of right ascension and grouped into 12 signs or *kong*. Both equator and ecliptic are divided into 12 parts of 30° each, designated by the same name. The catalog, as published by the Zo-Sè Observatory, gives for each of the 3,083 stars, 1° a current number, 2° the Chinese name of the star, 3° the right ascension for 1744 in degrees, minutes and seconds, 4° the precession in right ascension in seconds and thirds, 5° the declination for 1744, 6° the precession in declination in seconds and thirds, 7° the right ascension for 1875, in hours, minutes and tenths of a minute, 8° the declination for 1875 in degrees and minutes, 9° the European and scientific name of the star. Numbers 1 to 6 are the plain translation of the Chinese data; numbers 7 to 9 were computed by Rev. P. Tsutsihashi, S. J.

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[1] A description of some of the old instruments of the Pekin Observatory, looted by the French and German troops in 1900, appeared in the *Scientific American Supplement*, No. 1304, December 29, 1900, and was reprinted in the *Smithsonian Institution Report* for 1900, pages 185-186.

[2] *Annales de L'Observatoire Astronomique de Zô-Sè,* tome VII, année 1911, published in 1914.

Abridged Catalog.—According to the Chinese author, information about the numbers of constellations can be derived from three early Chinese catalogs. First, the astronomical section of the history of Han gives the number of constellations as 118 and of the stars as 783. Second, the history of Tsin refers to a chart of 283 constellations and 1,464 stars. Third, the astronomer, Nan Hoai-jen, namely, Rev. P. Verbiest, S. J., made a catalog of 259 constellations containing 1,129 stars. While 24 constellations and 335 stars, known to earlier Chinese astronomers, are not recorded in Verbiest's catalog, 597 stars and 23 southern constellations with 150 stars were added. The purpose of the Chinese authors of the present catalog was to revise and correct the old star catalogs, by measuring the distances between the stars, computing their positions, observing the forms of the constellations and recording them on a chart. The conclusion of the author, which gives an idea of the uranographic knowledge of the Chinese in 1744, is that there are 300 constellations, containing 3,083 stars. For the interest of the reader, I have compiled in the following table the number and name of the 28 *sicou*, the number of constellations in each, the number of stars found in early catalogs, the number of stars added in the new, and the number of stars recorded in the old catalogs that could not be found by the Chinese author of the present catalog:—

Sieou		Con-stellations	Number of Stars		
Number	Designation		Old	New	Missing
1	The Abode of the Horn	11	41	47	4
2	The High Residence	7	22	26	..
3	The Low Residence	11	35	41	19
4	The House	7	21	14	..
5	The Heart	2	5	8	10
6	The Tail	5	21	12	..
7	The Fan	3	8	1	..
8	The Bushel	10	52	40	10
9	The Ox	11	54	81	10
10	The Woman	8	54	65	1
11	The Funeral Hillock	10	34	22	..
12	The Ridge	10	50	70	6
13	The Spouse	10	106	46	3
14	The Wall	6	21	52	7
15	The Sandal	9	42	53	3
16	The Harvest-Woman	6	33	64	..
17	The Grain-Keeper	7	39	57	..
18	Mao	9	47	37	..
19	The Thread	14	89	84	3
20	The Beak	3	16	17	..
21	The August	6	25	49	..
22	The Well	19	63	124	7
23	The Manes	6	29	57	..
24	The Willow	2	11	15	..
25	The Stars	4	31	95	..
26	The Arc	1	6	4	..
27	The Wing	1	22	7	..
28	The Car	2	14	8	..

In all probability, the missing stars are to be explained by varying atmospheric conditions and the different physiological dispositions of the observer, if the explanation of a very few cases is not to be found in the minima of variables and very rare temporaries.

M. SELGA, S. J.

LICK OBSERVATORY, MOUNT HAMILTON,
December 15, 1914.

SPECTRA HAVING BRIGHT LINES, BY ANNIE J. CANNON.[1]

According to Miss CANNON, "Stellar spectra having bright lines may be divided into at least six classes," and the total number of known celestial objects with bright lines in their spectra is 750. The paper, of which this note is an abstract, discusses the first four of these classes—gaseous nebulæ, Class P; stars of Class O; stars of the P *Cygni* type, having bright lines superposed on a continuous spectrum; and Novæ. The discussion is based mainly upon photographs taken with the 8-inch Draper telescope at Cambridge and with the 8-inch Bache telescope at Arequipa.

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[1] *Annals Harvard College Observatory,* **76**, 19, 1914.

The four classes of objects are considered separately and are tabulated in convenient form for reference. The table of gaseous nebulæ gives for each object the position for 1900, with galactic co-ordinates added, and then, in nine columns, the intensities of the principal bright lines observed. In the tables for the stellar objects the intensities and identifications of the bright lines are omitted, but the Class O stars and the Novæ are divided into sub-classes according to their spectral peculiarities. The explanatory notes to the tables describe individual peculiarities, and give references to the literature of the subject.

Two plates are added to illustrate the various spectra with bright lines. R. G. AITKEN.

January 14, 1915.

THE MULTIPLE SYSTEM, ZETA CANCRI.

Zeta *Cancri* consists of a moderately close bright pair of stars (A and B), which form a binary revolving in nearly circular orbits with a period of about sixty years. A third bright star C revolves about the center of gravity of the binary pair in a much larger orbit, its motion so far as observed being approximately on the arc of a circle. There are, however, irregularities or anomalies in its motion which, because of their periodic recurrence, were ascribed by OTTO STRUVE and by FLAMMARION to the influence of a fourth star (D) near C and too dark to be visible in a telescope.

About twenty-five years ago, SEELIGER made a very thoro study of the measures of the three stars in the system, with special reference to the anomalies in the motion of C, and found that these could be entirely removed if we assume that C is attended by a dark companion, D, the pair revolving in nearly circular orbits at a mean distance of about $0''.2$ and in a period of a little less than eighteen years.

Burnham disputed this conclusion and considered that the observed irregularities in the motion of C about AB were simply due to the accumulation of systematic errors of measure. As a test of the question he proposed that measures be made of the difference in declination between C and a star (β 1243) independent of the system, which follows about 2^m and is about 104″ north of C. He began such measures with the 36-inch telescope in 1891 and he and Barnard continued the series regularly with that instrument, and, later, with the 40-inch of the Yerkes Observatory until 1905. Burnham added a later set in 1910, and at this time wrote: "There is nothing in these measures, begun in 1891, to indicate any variable motion in C."

Casual inspection would seem to support this conclusion, for the measures are remarkably accordant, and when reduced to a common epoch (1900.0) show apparently only a regular progressive increase in the distance due to the known relative proper motion of the two stars. Seeliger, however, in a recent article in the *Astronomische Nachrichten*[1] finds that, on closer analysis, they fully support his earlier investigation. If the measures are corrected simply for the relative proper motion and the mean is taken, the average residual of the measures from this mean is ± 0″.14, the range 0″.56. This would not be excessive in measures of this kind; but the residuals show a marked systematic run, being large and negative in 1891-1895, large and positive in 1899-1902, nearly zero in 1903-1905, and large and negative in 1910. When the correction for the orbital motion of C about the hypothetical star D is applied, the average residual is reduced to ± 0″.06, the range to 0″.29, and the systematic change of sign entirely disappears.

These measures, therefore, clearly support Seeliger's hypothesis, and the present investigation taken in connection with his former researches, satisfactorily establishes his finding that *ζ Cancri* is a quadruple system. R. G. Aitken.

January 15, 1915.

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[1] *Astronomische Nachrichten*, **199**, 273, 1914.

GENERAL NOTES.

San Francisco Meeting of the American Association for the Advancement of Science and Affiliated Societies, August 2-7, 1915.—At the Cleveland meeting of the American Association for the Advancement of Science in January, 1913, the Council of the association voted to hold a special meeting in San Francisco upon the occasion of the Panama-Pacific International Exposition. The plans for this meeting were placed in charge of a Pacific Coast Committee of thirty-one members. At an early meeting of the Pacific Coast Committee the date of the San Francisco meeting was set for the week beginning August 2d and terminating August 7, 1915. Plans have been made to hold the general meetings of the association as a whole in the Scottish Rite Auditorium in San Francisco. Thru the courtesy of the two California universities in the vicinity of San Francisco, the section meetings and many of the meetings of affiliated societies will be held at the University of California, Berkeley, and on one day, Wednesday, August 4th, at Stanford University, near Palo Alto.

The following resolution was adopted at the first meeting of the Committee on Scientific Program appointed by the Pacific Coast Committee:—

> In view of the fact that the occurrence of scientific meetings in San Francisco in 1915 is in a manner a part of the celebration commemorating the opening of the Pacific to the peoples bordering the Atlantic, it seems fitting that the program of meetings held in connection with this celebration should relate, as far as possible, to problems of world interest which pertain especially to the Pacific area.

In accordance with this recommendation, it has been possible in many cases to arrange for consideration of Pacific problems of far-reaching significance by the sections and societies intending to participate in these meetings.

The opening session of the convocation week will occur on Monday morning, August 2d. Following the presidential address on Monday evening, a reception will be tendered to the visiting scientists. On Tuesday evening Dr. FRIDTJOF NANSEN, of Norway, will present an address upon problems of oceanography. The sessions on Wednesday will be held at Stanford University, thirty miles south of San Francisco. Wednesday evening has been reserved for informal dinners of various societies. Professor R. A. DALY, of Harvard University, will present an address on Thursday evening upon the geologic and biologic problems of the Pacific Islands, and on Friday evening Professor W. B. SCOTT, of Princeton University, will discuss the influence of former separation of North and South America on the evolution of the faunas of America. On Saturday evening, August 7th, an address will be presented on problems concerning the peoples of the Pacific area.

In addition to the general addresses, intended for all sections of the association and all affiliated societies, there will be many simultaneous or alternating meetings for the presentation of addresses and papers in the principal divisions of scientific knowledge, prepared jointly under the auspices of the American Association and of societies which are related by common interest. The following societies have already determined to participate in the San Francisco meeting of the American Association either by holding meetings during the convocation week or by meeting in conjunction with sections of the American Association:—

American Mathematical Society, American Astronomical Society, Geological Society of America, Palaeontological Society, Seismological Society of America, Biological Society of the Pacific, Entomological Society of America, American Academy of Political and Social Science, American Political Science Association (Pacific Coast Branch), American Anthropological Association, Archæological Institute of America, American Phytopathological Society, American Genetic Society. Other societies will also hold meetings, arrangements for which are not yet complete.

Those intending to contribute papers are requested to send the titles to the appropriate committee as soon as possible, and to forward copies of their papers with abstracts of contents well in advance of the meeting. It will not be possible to place upon the program papers which are received by the program committees at a date later than July 26, 1905.

COMMITTEE ON PROGRAM FOR MATHEMATICS AND ASTRONOMY.

M. W. HASKELL, Chairman, University of California, Berkeley.
R. G. AITKEN, Lick Observatory, Mount Hamilton, California.
GEORGE E. HALE, Mount Wilson Solar Observatory, Pasadena, California.
L. M. HOSKINS, Stanford University, California.
A. O. LEUSCHNER, University of California, Berkeley.
SIDNEY D. TOWNLEY, Stanford University, California.

A joint session of the American Mathematical Society, the American Astronomical Society and Section A will be held on Tuesday, August 3d, at the University of California for the presentation of two addresses: "The Human Significance of Mathematics," by Professor C. J. KEYSER, Columbia University, New York; "Recent Progress in the Development of Astronomical Science," by Dr. GEORGE E. HALE, Mount Wilson Solar Observatory.

Following this session, the American Mathematical Society and the American Astronomical Society will hold sessions at Stanford University and at the University of California.

MOUNT HAMILTON TRIP.

On Friday, August 6th, the American Astronomical Society and others interested in astronomical research will make an excursion to the Lick Observatory, Mount Hamilton.

MOUNT WILSON TRIP.

The director of the Mount Wilson Solar Observatory extends a cordial invitation to men of science interested in astronomical and physical research to visit the observatory either before or after the San Francisco meeting of the association. The shops and laboratories in Pasadena and the observatory buildings on Mount Wilson will be open, and all phases of the work in progress can be seen. The Mount Wilson Hotel Company maintains a daily auto-stage service between Pasadena and the summit, where comfortable accommodations for the night may be found at the hotel. If time is limited, the round trip from Pasadena can be made in a day.

The Astronomical Prizes of the French Academy of Sciences are this year all awarded to French astronomers. The most notable award is that of the Prix Damoiseau, which goes to M. A. GAILLOT, for his revision of LE VERRIER'S Tables of *Jupiter*. In 1902 the subject set for the same prize was the improvement of the Tables of *Saturn*, while in 1907 the subject for the *Prix de Pontecoulant* was the improvement of the Tables of *Neptune* and *Uranus*. These two prizes had likewise been awarded to M. GAILLOT, who now, at the age of 80 years, has the satisfaction of completing the great work of revising the theory of the four major planets.

The Prix Lalande goes to M. JOSEPH-NOËL GUILLAUME for the whole of his astronomical work. M. GUILLAUME began his career as an amateur astronomer, but has been connected with the Lyons Observatory since 1892. He is known especially for his long series of observations of solar phenomena, but has also made numerous micrometric measures, as well as observations of lunar occultations and of the phenomena of *Jupiter's* satellites.

The Prix Valz is divided between M. PIERRE SALET and P. STANISLAS CHEVALIER. The former is an astronomer in the Paris Observatory, whose chief researches relate to polarization phenomena, tho he has also made many contributions in other fields. The latter is director of the observatory at Zo-Sé, near Shanghai, China, and his chief attention has been devoted to studies of solar phenomena.

The Prix Janssen is awarded to M. JARRY-DESLOGES, the well-known amateur astronomer whose observatory is located on the North African plateau, near Algiers, at an altitude of 1,113 meters. His work has been almost exclusively the study of planetary details, particularly those of *Mars*, and it is for the results obtained that the award is made.

Other awards made by the Academy include a Wilde prize of 2,000 francs to M. SCHULHOF, of the Bureau of Longitudes, for his extensive researches on comets and minor planets and the following allotments from the Fonds Bonaparte: 3,000 francs to M. FR. CROZE to permit him to continue his investigations of the Zeeman effect in spectra; 2,000 francs to P. LAÏS, director of the Vatican Observatory, to assist in the publication of a portion of the *Carte du Ciel*; 2,000 francs to M. TROUSSET, assistant at the Bordeaux Observatory, to aid him in his studies of the theory of minor planets; and 4,000 francs to M. ANDOYER, of the University of Paris, to allow the continuation of the work of preparing new fundamental tables of logarithms.

Attention may again be called to the admirable *Observers' Handbook*, edited by Dr. C. A. CHANT and published annually by the Royal Astronomical Society of Canada. Many of the tables, for example, those of times of sunrise and sunset, are, of course, calculated for Canadian latitudes, but other portions of the little book will be found convenient by amateur observers anywhere in the northern hemisphere. Such are, for example, the lists of various objects of interest,—double stars, variable stars, the brighter stars in the sky, the predictions for the principal meteor showers, and the descriptions of the planetary motions and of the constellations, arranged according to months. Useful charts, on a convenient scale, showing the stars to the fifth magnitude are also included.

Aid to Astronomical Research.—A communication under this title of more than usual interest is given by Professor E. C. PICKERING in *Science* for January 15, 1915. Experience with the Rumford, Elizabeth Thompson, and other funds having shown that great returns may be secured by the use of relatively small grants of money to suitable persons, Professor PICKERING addressed a circular letter to twelve of the leading astronomers in America. In this letter he requested brief statements as to the use that would be made of such grants of perhaps one thousand dollars per year for five years.

It is impossible to quote, even in abstract, the replies which were received; for this we must refer the reader to the original article. The replies are of great interest in that they show not only how much could probably be accomplished by grants of this amount, but more especially, in that they give, in large measure, a conspectus of the different fields of astronomical endeavor which are considered to be of the greatest importance by America's leading astronomers. A majority of the writers desires additional computers and measurers for the furtherance of parallax programs, and two wish assistants or measurers in connection with spectrographic researches.

"An unexpected result," writes Professor PICKERING, "was that, in nearly every case, the principal need proved to be for assistants. Some preferred one experienced observer, others two computers. . . . An astronomer can often direct one or two assistants so that they will obtain as accurate results as if he devoted the same time to the work himself. A small appropriation may thus double the output of an observatory. . . . Even if only a portion of the sum asked for could be provided, it is probable that an extraordinary relative output would be obtained. It is hoped that, in some cases, those interested in a particular observatory may be willing to supply its needs."

One of the two Royal Medals presented annually by the Royal Society of London has been bestowed on Dr. E. W. BROWN, of Yale University, for his researches on the motion of the Moon.

Owing to the war the management of the *Zentralstelle für Astronomische Telegramme*, by agreement with Professor KOBOLD, has been passed over to Professor ELIS STRÖMGREN, of the Copenhagen Observatory.

The occupation of Antwerp by the Germans occasioned the temporary suspension of the *Gazette Astronomique*, formerly issued by the Astronomical Society of Antwerp. A number of English astronomers have given financial assistance, and it is intended to resume the *Gazette* early in January; it will be published both in French and English. The minimum subscription will be five shillings annually, but it is suggested that those who feel able and willing to contribute more liberally send half a guinea or a guinea as a means of more effectively aiding in the rehabilitation of this journal. Subscriptions and correspondence should be sent to FÉLIX LE ROY, Honorary Secretary, 29 Stamford Street, London, S. E.

Professor W. S. ADAMS, of the Solar Observatory at Mount Wilson; M. HENRI ANDOYER, Professeur à la Sorbonne, Paris, and Director FRANK SCHLESINGER, of the Allegheny Observatory, were recently elected Associates of the Royal Astronomical Society.

We regret to announce the death of Professor N. C. DUNÉR, at Upsala, in his seventy-sixth year. His researches covered a wide field; he has made valuable contributions to astronomical science in the fields of double stars and variable stars, and also in astronomical spectroscopy, but is perhaps best known for his spectroscopic studies of the rotation of the Sun.

Mr. A. MASSINGER, assistant in the Royal Observatory at Heidelberg, died in battle near Ypres on October 21, 1914.

Drs. FREUNDLICH and ZURHELLEN, with five other members of the various German eclipse expeditions to Russia, being reservists in the German army, were not allowed to leave Russia, but are detained in Odessa. It is stated in *Sirius* that they have the freedom of the city and are not treated in any way as ordinary prisoners of war. From *Popular Astronomy* we learn that Dr. MÜNCH is wounded and a prisoner in France, and that Dr. LIEBMANN has been killed. Professor BAUSCHINGER is a temporary terminus commander at Strassburg, while Professor SCHWARZSCHILD is conducting a military meteorological station at Namur in connection with the aeroplane service.

At the Philadelphia meeting of the American Association for the advancement of Science, Dr. W. W. CAMPBELL was elected President of the association, and Dr. A. O. LEUSCHNER Vice-President for Section A (Mathematics and Astronomy).

Among the bequests made by the will of Mrs. DRAPER is one of $150,000 for the Draper Memorial of Harvard College Observatory, established in memory of Dr. HENRY DRAPER, her husband, whose photographic plates and apparatus are also bequeathed to the observatory.

A cablegram to the daily papers says that when the war broke out the Prussian military authorities requisitioned the famous trained horses of Elberfeld. Dr. VOGEL, their owner, protested and the Royal Academy of Berlin supported the protest. A reprieve was granted, but later the horses were requisitioned for an artillery battery and their death on a Flanders battlefield has just been announced. It will be remembered that the "thinking horses" of Elberfeld were first brought to the attention of the public some years ago by their trainer, Herr K. KRALL, who exhibited them at various places in Germany.—*Science,* December 25, 1914.

ADDENDUM TO THE MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY ON NOVEMBER 28, 1914, AT 2:00 P. M., TO CONSIDER THE AWARD OF THE BRUCE GOLD MEDAL FOR THE YEAR 1915.

There were present President CRAWFORD and Directors AITKEN, CUSHING, COSTA and RICHARDSON. The proxies of Directors BURCKHALTER, TOWNLEY and MARKWART were held by Director RICHARDSON. Letters of nomination, in accordance with the statutes for the bestowal of the Bruce Medal, were read from the directors of the observatories of Harvard, Yerkes, Lick, Paris, Berlin, and Greenwich.

After full discussion, the Board by unanimous vote, awarded the medal for 1915 to

DR. W. W. CAMPBELL,
Director of Lick Observatory.

Owing to war conditions in Europe, making it impossible, at the present time to secure the medal from the French Mint in time for presentation at the annual meeting of the Society in January, it was decided to defer the actual presentation until some appropriate date later in the year, notice of which will be duly communicated to members.

Adjourned.

D. S. RICHARDSON,
Secretary.

The following correspondence was exchanged between the Secretary and Dr. CAMPBELL:—

December 2, 1914.

DR. W. W. CAMPBELL,
Director of Lick Observatory,
Mount Hamilton, California.

My dear Sir: It gives me particular pleasure to inform you that, at a special meeting of the Board of Directors of the Astronomical Society of the Pacific, held on the 28th ultimo in this city, to consider the award of the Bruce Gold Medal for the year 1915, it was decided by unanimous vote that the honor belonged to you, and I was instructed to ask your acceptance of same.

In performing this pleasant duty, I venture to express the conviction that the members of the Astronomical Society will find more satisfaction in this award than in any previously made—and all have been worthily bestowed.

In recognizing your eminent services to astronomy—based as they are upon the consent of your scientific brethren in all parts of the world—it is our particular good fortune to be able, at the same time, to recognize a fellow member of our Society, a distinguished citizen of our State and a man whom we are permitted to call our friend.

Asking that you will kindly indicate your acceptance of the medal, and with sincerest personal regards, I beg to remain,

Very respectfully yours,
D. S. Richardson,
Secretary.

Mount Hamilton, December 14, 1914.

Dear Mr. Richardson:

Your letter of December 2nd reached Mount Hamilton about three hours after I had started to Chicago, and it finds me at home this morning.

It gives me extreme pleasure to accept the award of the Bruce Gold Medal of the Astronomical Society of the Pacific. I feel that the award of the Bruce Medal is the greatest honor which an astronomer can receive, and it is especially gratifying that our Astronomical Society of the Pacific is the organization concerned. The high value which astronomers in general assign to the Bruce Gold Medal award is due in part to the unique method of nominating the recipient, and also to the care which the Directors of the Astronomical Society of the Pacific have always exercised in acting upon the recommendations.

When the first opportunity presents itself, will you kindly inform the Board of Directors of the Society that I accept the award with a high sense of the honor they have conferred upon me?

Yours cordially,
W. W. Campbell.

Mr. D. S. Richardson, Secretary,
The Astronomical Society of the Pacific,
No. 752 Phelan Building,
San Francisco, California.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY ON JANUARY 30, 1915, AT 7:15 P. M.

There were present: President R. T. Crawford and Directors R. G. Aitken, B. A. Baird, S. D. Townley, C. S. Cushing, Charles Burckhalter, J. Costa and D. S. Richardson.

A verbal report was made by Director Cushing, of the Finance Committee, relative to the three first mortgage five per cent bonds, issued by the Contra Costa Water Company and owned by this Society. On motion of Director Aitken, seconded by Director Burckhalter, the following resolution was unanimously adopted:—

Resolved, That all questions relating to the three first mortgage five per cent bonds issued by Contra Costa Water Company owned by this Society be, and the same are hereby referred to the Finance Committee, with power to act in all matters pertaining to the same, including the reorganization of the company, or companies, owning the property covered by the lien of said bonds.

After further discussion, and in view of the fact that the necessity might arise of withdrawing the three bonds above mentioned from the custody of the Mercantile Trust Company, where they are at present on deposit, the following resolution was offered by Director CUSHING. It was seconded by Directors AITKEN and COSTA and unanimously carried:

Resolved, That the President, or either Vice-President, and Secretary of this Society be, and they are hereby, authorized to withdraw from possession of Mercantile Trust Company of San Francisco and receipt for the three first mortgage bonds issued by the Contra Costa Water Company and on deposit with said trust company.

Adjourned.

D. S. RICHARDSON,
Secretary.

MINUTES OF THE ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ASSEMBLY HALL OF THE PHELAN BUILDING, SAN FRANCISCO, CAL., ON JANUARY 30, 1915, AT 8:00 P. M.

President R. T. CRAWFORD was in the chair. There being no objection, the minutes of the previous annual meeting were approved as printed.

Reports of committees were called for.

Director CUSHING, Chairman of the Finance Committee, reported that the accounts of the Treasurer had been carefully audited and found to be correct. He also reported that steps were being taken which he believed would result in an early and satisfactory adjustment of all matters growing out of the default upon the three Contra Costa Water Company bonds held by the Society.

Mr. RICHARDSON, of the Library Committee, reported that no additions had been made to the library during the past year other than the regular unbound exchanges.

Mr. F. R. ZIEL, of the Bruce Medal Committee, reported that he had communicated with the French Mint, in Paris, and learned that, owing to war conditions, it would not be possible at present for the mint to strike off the needed medal for the current year.

The report of the Donohoe Comet-Medal Committee was read by the Secretary. This report shows that five comets were discovered in 1914 and that medals were awarded to Messrs. KRITZINGER, ZLATINSKY, and NEUJMIN. Comet *e* 1914 was discovered by several observers, independently, on the same night. The committee withholds the award for the discovery pending the receipt of further data.

All of the foregoing reports were received and approved.

President CRAWFORD then announced the award of the Bruce Gold Medal for the year 1915 to Dr. W. W. CAMPBELL, Director of Lick Observatory. Owing to the difficulty, already noted, of procuring the medal at this time, he stated that some future date would be fixed upon for a more formal presentation ceremony.

The next business in order was the election of a Board of Directors and a Publication Committee for the ensuing year. Mr. BEVERLEY L. HODGHEAD, Chairman of the Nominating Committee, submitted the following ticket:—

For Board of Directors: W. W. CAMPBELL, W. H. CROCKER, C. S. CUSHING, J. COSTA, F. V. CORNISH, D. S. RICHARDSON, R. G. AITKEN, CHARLES BURCKHALTER, A. O. LEUSCHNER, S. D. TOWNLEY, A. H MARKWART.

For Publication Committee: R. G. AITKEN, H. D. CURTIS.

Messrs. ZIEL and COSTA were appointed by the chair as tellers, and the ballots were distributed to members present, to be collected and counted at the close of the address of the evening.

President CRAWFORD then introduced the speaker of the evening, Professor E. E. BARNARD, of Yerkes Observatory.

The announcement that this distinguished astronomer was to speak had called out a large and most attentive audience, which greatly enjoyed his wonderful illustrations and descriptions of the darker and more obscure regions of the sky, into the depths of which his keen vision has doubtless penetrated more deeply than that of any man who has lived.

At the close of his address a cordial vote of thanks was voted by the meeting.

The tellers then announced that the Board of Directors and Publication Committee, as nominated, had been unanimously elected.

Adjourned.

D. S. RICHARDSON,
Secretary.

MINUTES OF THE NEWLY ELECTED BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, IN THE ROOMS OF THE SOCIETY, 752 PHELAN BUILDING, SAN FRANCISCO, ON JANUARY 30, 1915, AT 9:30 P. M.

There were present Directors CUSHING, COSTA, AITKEN, BURCKHALTER, TOWNLEY and RICHARDSON.

The Board was called to order by Director BURCKHALTER, who had been made temporary chairman.

The only business on hand was reorganization, which resulted in the election of the following officers for the ensuing year:—

President: R. G. AITKEN.
First Vice-President: S. D. TOWNLEY.
Second Vice-President: J. COSTA.
Third Vice-President: F. V. CORNISH.
Secretary and Treasurer: D. S. RICHARDSON.

The newly elected President appointed the following committees:—

Finance Committee: C. S. Cushing, Wm. H. Crocker and A. H. Markwart.

Comet-Medal Committee: W. W. Campbell, R. H. Tucker and H. D. Curtis.

Library Committee: A. O. Leuschner, F. V. Cornish and D. S. Richardson.

Adjourned.

D. S. Richardson,
Secretary.

Report of the Treasurer of the Astronomical Society of the Pacific for the Fiscal Year ending January 30, 1915.

GENERAL STATEMENT.

Securities held, 17 bonds, estimated value	$17,154 69
Cash in William Alvord Fund	384 87
" " Library Fund	99 78
" " John Dolbeer Fund	467 98
" " Bruce Medal Fund	635 67
" " Life Membership Fund	71 07
" " Donohoe Comet-Medal Fund	923 83
" " General Fund	324 74
Total assets	$20,062 63

No liabilities.

STATEMENT BY FUNDS.

WILLIAM ALVORD FUND.

Dr.		
To Cash Balance January 31, 1914	$384 87	
Bond and Bank Interests	160 44	$ 545 31
Cr.		
By Transfers to General Fund		160 44
Cash Balance January 30, 1915		$ 384 87

Securities held, 4½ bonds, estimated value, $4,570.25.

LIBRARY FUND.

Dr.		
To Cash Balance January 31, 1914	$138 98	
Bond and Bank Interests	140 80	$ 279 78
Cr.		
By Transfers to General Fund		180 00
Cash Balance January 30, 1915		$ 99 78

Securities held, 3½ bonds, estimated value, $3,573.75.

JOHN DOLBEER FUND.

Dr.		
To Cash Balance January 31, 1914	$467 98	
Bond and Bank Interests	233 83	$ 701 81
Cr.		
By Transfers to General Fund		233 83
Cash Balance January 30, 1915		$ 467 98

Securities held, 4½ bonds, estimated value, $4,527.22.

LIFE MEMBERSHIP FUND.

Dr.		
To Cash Balance January 31, 1914	$ 69 31	
Bank and Bond Interests	93 13	$ 162 44
Cr.		
By Transfers to General Fund		91 37
Cash Balance January 30, 1915		$ 71 07

Securities held, 2 bonds, estimated value, $1,996.25.

BRUCE MEDAL FUND.

Dr.		
To Cash Balance January 31, 1914	$488 81	
Bond and Bank Interests	146 86	$ 635 67
Cash Balance January 30, 1915		635 67

Securities held, 2½ bonds, estimated value, $2,487.22.

DONOHOE COMET-MEDAL FUND.

Dr.	
To Cash Balance January 31, 1914	$ 887 99
Bank Interests	35 84
Cash Balance January 30, 1915	$ 923 83

THE GENERAL FUND.

Dr.		
To Balance January 31, 1914	$578 63	
John Dolbeer Fund	233 83	
William Alvord Fund	160 44	
Life Membership Fund	91 37	
Library Fund	180 00	
Special Donation from Unknown Friend	100 00	
Sale of *Publications*	31 00	
Membership Dues	579 50	
Total Receipts		$ 1,954 77
Cr.		
By Blair-Murdock Company, printing	$994 14	
Sunset Publishing House, half-tones	29 10	
Rent of rooms	242 50	
Salary, Secretary-Treasurer	240 00	
Engraving Comet-Medals	5 64	
Shelving for Library	10 25	
Crocker safe-deposit box	4 00	

Taxes	$ 18 31	
Expressage on *Popular Astronomy*	2 90	
Insurance on Library	6 90	
Transferred to Library Fund	37 50	
Transferred to Bruce Medal Fund	12 50	
Special clerical services	5 00	
Incidental expenses Bruce Medal	3 00	
Postages and incidentals	18 29	$ 1,630 03
Balance January 30, 1915		$ 324 74

FUNDS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD IN DEPOSIT BY THE MERCANTILE TRUST COMPANY OF SAN FRANCISCO, AT 464 CALIFORNIA STREET.

These securities are all of the face denominations of $1,000, and the values given represent their original cost to the Society.

Life Membership Fund.	
One South Pacific Coast Railroad Company's 1st mortgage, guaranteed 4 per cent Gold Bond, No. 3406. Principal due July, 1937; interest payable in January and July	$1,000 00
One Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 712. Principal due July 1, 1934; interest payable January 1st and July 1st	996 25
Alexander Montgomery Library Fund.	
One Oakland Transit consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4328. Principal due July, 1932; interest payable January and July	1,040 00
One Contra Costa Water Company's 5 per cent Gold Bond, No. 1665. Principal due January, 1915; interest payable January and July.	1,035 00
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 714. Principal due January 1, 1934; interest payable January 1st and July 1st	497 50
One Blue Lakes Water Company 6 per cent 1st mortgage Gold Bond, No. 380. Principal due 1938; interest payable March 15th and September 15th	1,001 25
Bruce Medal Fund.	
One Bay Counties Power Company 1st consolidated mortgage 5 per cent sinking fund Gold Bond, No. 1636. Principal due September, 1930; interest payable March and September	1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6836. Principal due September, 1922; interest payable in March and September	977 22
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 714. Principal due January 1, 1934; interest payable January 1st and July 1st	497 50
John Dolbeer Fund.	
One South Pacific Coast Railway Company's 1st mortgage 4 per cent guaranteed Gold Bond, No. 3407. Principal due July, 1937; interest payable in January and July	1,000 00
One Oakland Transit consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4329. Principal due July, 1932; interest payable January and July	1,040 00

One Bay Counties Power Company 1st consolidated mortgage 5 per cent sinking fund Gold Bond, No. 1637. Principal due September, 1930; interest payable March and September	$ 1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6837. Principal due September, 1922; interest payable in March and September	977 22
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 713. Principal due January 1, 1934; interest payable January 1st and July 1st	497 50
William Alvord Fund.	
Two Contra Costa Water Company's 5 per cent Gold Bonds, Nos. 87 and 1666. Principal due January, 1915; interest payable in January and July	2,071 50
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 713. Principal due January 1, 1934; interest payable January 1st and July 1st	497 50
One Blue Lakes Water Company 6 per cent 1st mortgage Gold Bond, No. 381. Principal due 1938; interest payable March 15th and September 15th	1,001 25
One Moulton Irrigated Lands Company 6 per cent 1st mortgage Gold Bond, No. 144. Principal due December 15, 1918; interest payable June 15th and December 15th	1,000 00
Seventeen bonds, original cost	$17,154 69

NOTE.—The three Contra Costa Water Company's 5 per cent Gold Bonds held by the Society, viz: Nos. 87, 1665 and 1666, were due and payable on January 1, 1915. Same have not been paid. There is also due the Society interest on these bonds for the year 1914, amounting to $150.00.

During the year 1914 ten new members were added to the Society. There were eight deaths and three resignations.

D. S. RICHARDSON,
Secretary-Treasurer.

The undersigned, constituting the Auditing Committee of the Society, have examined the foregoing accounts and found them to be correct.

CHARLES S. CUSHING,
FRANK V. CORNISH,
B. A. BAIRD,
Auditing Committee.

OFFICERS OF THE SOCIETY

Mr. R. G. Aitken .... *President*
Mr. S. D. Townley .... *First Vice-President*
Mr. J. Costa .... *Second Vice-President*
Mr. F. V. Cornish .... *Third Vice-President*
Mr. D. S. Richardson .... *Secretary and Treasurer*

Board of Directors—Messrs. W. W. Campbell, W. H. Crocker, C. S. Cushing, J. Costa, F. V. Cornish, D. S. Richardson, R. G. Aitken, Charles Burckhalter, A. O. Leuschner, S. D. Townley, A. H. Markwart.

Publication Committee—Messrs. R. G. Aitken, H. D. Curtis.

Finance Committee—Messrs. C. S. Cushing, W H. Crocker, A. H. Markwart.

Comet-Medal Committee—Messrs. W. W. Campbell, R. H. Tucker, H. D. Curtis.

Library Committee—Messrs. D. S. Richardson, F. V. Cornish, A. O. Leuschner.

NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished free of cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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ON ATMOSPHERIC CONDITIONS REQUIRED FOR ASTRONOMICAL OBSERVATION.

By W. W. Campbell.

The importance of good atmospheric and general conditions for astronomical research has probably been realized by every observing astronomer since the days of Sir Isaac Newton. Newton called attention to the important fact that however perfect a telescope may be there yet remain certain limitations to its performance, arising from imperfections in the atmosphere thru which the observer looks. Newton commented that the only remedy is "a serene and quiet air, such as may perhaps be found on the tops of the highest mountains above the grosser clouds." I have for many years ardently admired Newton's use of the word "perhaps" in this connection.

Notwithstanding the value which astronomers in general have for many generations placed upon good conditions, they have been obliged to accept conditions as they exist near the cities and universities with which their life has been associated, with only a few exceptions, almost up to the present generation of astronomical workers. There was the expedition of Piazzi-Smyth to the Peak of Teneriffe, principally to answer the question, "How much can astronomical observation be benefited by eliminating the lower part of the atmosphere?" Green went to Madeira in 1877 to observe *Mars*, partly because of more tranquil atmosphere than at his home station, and partly to have *Mars* transit the meridian at a greater altitude. Tacchini constructed an observatory on Mount Etna. Janssen's observatory on the summit of Mount Blanc was a heroic effort for better atmospheric conditions. Langley conducted a notable expedition to Mt. Whitney, and there have been several similar undertakings. Strenuous efforts were made to induce JAMES LICK to locate his observatory in the Sierra Nevada Mountains, at an altitude not less than 10,000 feet, but other counsel persuaded him to select an altitude of only 4,200 feet. Many other observatories have in recent years been located on the summits of mountains or on plateaus. The most extensive tests at prospective observing stations have been made by the Harvard College Observatory, notably by Professors BAILEY and WILLIAM H. PICKERING on the west coast of South America, by Professor BAILEY in South Africa, and by Professor PICKERING in Mexico, Southern California, Arizona and the West Indian Islands. COPELAND in the early 1880's tested many stations in the high equatorial regions of South America. Eclipse observers have reported upon conditions at a multitude of widely distributed stations occupied by their expeditions. Messrs. WRIGHT and CURTIS, when successively in charge of the D. O. Mills Expedition to the southern hemisphere, made careful tests of many places in Central Chile, thruout a range of several degrees of latitude. Under the auspices of the Carnegie Institution, Professor HUSSEY tested the conditions existing at several promising stations in Southern California, Arizona, and Australia. Many observers have thought that the best conditions could perhaps be found on some of the small tropical islands, tho the reports by eclipse observers are somewhat conflicting as to the merits of an insular location, and the experience of Sir DAVID GILL on Ascension Island was not favorable. In *The Observatory*, Vol. 36, pages 401-404, Professor WILLIAM H. PICKERING made a strong plea for the tropical island, as a result of his experiences at Mandeville, Jamaica, at an altitude of 2,100 feet above sea-level, with an 11-inch refractor. The disadvantage of the usual enervating effects of tropical climate is readily avoided, he says, by ascending to a moderate altitude. He claims for his station a larger proportion of clear nights than exist in the eastern part of the United States or in the temperate zone generally, clearer sky, greater freedom from night winds, a command of a larger area of the heavens, greater personal comfort of the observer, and, most important of all, the better definition of the objects observed. The best "seeing" at Harvard Observatory ranges from 6.2 to 6.5 on the scale of 10 for perfection, whereas at Mandeville it reaches 8.8. The steadiness and definition of stellar images for objects within 30° of the horizon at Mandeville is as good as the steadiness and definition of objects within 30° of the zenith at Harvard. He states that the terminator of the Moon as viewed with a power of 350 diameters is absolutely sharp, without the slightest perceptible motion or vibration, on one night in three on the average thruout the year. To quote his very strong sentence on the subject: "Under these circumstances it would appear that we are seeing the Moon as clearly as we should if our own atmosphere were entirely removed." Many experienced observers will naturally look twice at the quoted sentence, because of the superlative degree employed therein.

Professor PICKERING's explanation of the better conditions existing in the tropics is based upon HAHN's conclusion that the great anti-cyclones which sweep the temperate zones, mixing the air of different strata, are more frequent in the United States than in any other portion of the world. These, in his opinion, are the source of the disasters to astronomical definition. He says: "It is doubtful if any portion of the civilized world can furnish poorer seeing than is usually found in our Eastern States," whereas the anti-cyclones reach down to the tropics only once in a great while. Professor PICKERING's opinion is "that in the future many of the large observatories of the world will maintain tropical sub-stations, furnished with instrumental equipments of the very finest quality, and that from these stations most of the world's observing will ultimately be done." The opinion of many astronomers has long been to the effect that such tropical locations as Professor PICKERING describes must have great merit, and they have examined the map of the world with longings to make tests on certain tropical islands.

Professor PICKERING does not comment upon the Jamaican conditions for observations of the Sun.

It had seemed to many that the Kodaikanal Observatory, near the southern point of India, latitude 10° north, should possess excellent observing conditions. The mountain peak upon which the observatory stands has a large and relatively flat top, altitude 7,700 feet, and the instruments are not near any steep slopes. The excellent results which flow from the Kodaikanal Observatory are assurance that the combination of observers, instruments and observing conditions has a high mean value.

Bulletin No. 42, recently issued by the Kodaikanal Observatory, calls attention to the fact that the atmospheric conditions at that station, at least for solar observations, are extremely poor in comparison with the conditions which Director EVERSHED has found to exist on the floor of the Kashmir Valley, in the north temperate zone, latitude 34°. The floor of the Kashmir Valley is 5,200 feet above sea-level, and is some 15 or 20 miles wide by about 80 miles long. The valley is completely surrounded by high mountains, ranging from 15,000 feet above sea-level on the southwest side to more than 20,000 feet on the north and northeast sides. In August and October, 1913, and again in May, June, and July, 1914, extensive atmospheric tests were conducted in the vicinity of Srinagar, on the floor of the valley. In 1914, both before and while the Kashmir tests were under way, comparative observations were made at Kodaikanal. The superiority of the conditions in the Kashmir Valley was strongly marked. At Kodaikanal, as at many other mountain observatories, solar observations have generally to cease when the morning Sun reaches an altitude of 25° or 30°, because the images become extremely unsteady. In the Kashmir Valley, on the contrary, the solar images were excellent to start with and retained their excellence thruout the day. Several stations were occupied in the floor of the Kashmir Valley, and a few observations were made at selected points on the mountain slopes surrounding the valley. The day-time atmospheric conditions in the valley were notably superior to those at the higher altitudes. The best conditions in the valley were at a station surrounded by lakes and flooded rice fields. The night conditions on the slopes were better than the day conditions, but not so good as the night conditions in the valley.

The number of hours of sunshine at Kodaikanal and Srinagar are shown by the records to be practically the same, 2,028 hours per annum. EVERSHED estimates, "that at Kodaikanal not more than one hour in six of bright sunshine is available for photography, or for detailed spectrographic study, because of unsteady solar images, whilst in Kashmir at least five hours out of six would be available—a very conservative estimate would give four times the opportunity for work in Kashmir as compared with Kodaikanal, and in addition the quality of the material which could be secured at all times in Kashmir would be equal to the very best that Kodaikanal can produce on occasions when the definition is really good."

EVERSHED's atmospheric tests in New Zealand have led him to select the summit of a low hill near the coast line for the site of the Cawthorn Observatory. The definition on the higher hills in the same neighborhood, so far as solar observations were concerned, were poorer than on the low hills. I understand that Mr. EVERSHED regards the tropics as unfavorable for observations of the Sun. Director EVERSHED's paper does not describe the *night* conditions existing at Kodaikanal. A full report on this subject would be read with great interest.

It should be said that many conditions, atmospheric and general, concern the advantageous location of an observatory. Much depends upon the nature of the observatory's program, and something upon the size of the instruments to be employed. The heavy deposit of dew which characterizes tropical stations in general may not be important with small instruments, but it might be very serious with large refractors or large reflectors. This point has not been adequately tested. The clouds come quickly and go quickly in the tropics. This factor is comparatively unimportant when the equipment consists of a small telescope, and the observations are visual or involve only short photographic exposures; but it would be extremely serious for a large institution whose observations are principally photographic, and especially so if the exposures are long. In the first case the observer can open his dome quickly and proceed at once with his observations: in the latter case a couple of hours in the late afternoon may be spent in getting the extensive instrumental equipment ready for observation, and clouds may render his preparations useless, or he may be in the midst of a three-hour exposure when the clouds compel him to cease observing and to throw away the partially-exposed plate. One of the valued conditions on Mount Hamilton is that the nights are in general entirely clear thruout their whole duration, or are entirely cloudy thruout their whole duration. When clouds do arrive in the course of the night they frequently render absolutely useless many hours of hard work devoted to the adjustments and to the first part of the exposure necessary to give the photographic image the desired intensity. The administration of a great observatory with fair economy and efficiency depends not only upon atmospheric conditions but upon general conditions. I can conceive of no plan so inefficient and unwise as that of locating a permanent observatory on a high mountain peak, such as Mount Whitney or Mont Blanc. Such a location would be practically useless during the large majority of the months of the year, and the connections of such an observatory with the outside world, maintained at great risk year after year, would sooner or later involve tragedies not justified by the scientific results.

ASTRONOMICAL OBSERVATIONS IN 1914.

Made by TORVALD KÖHL, at Odder, Denmark.

VARIABLE STARS.

(The instrument used is a 3-inch Steinheil, power 42.)

S *Ursæ Majoris*.[1]

Jan. 17:	S 2 steps < e.	Aug. 24:	2 steps < e.
Feb. 4:	= d.	27:	4 steps < e.
17:	1 step < d.	31:	3 steps < e.
27:	4 steps > d.	Sept. 6:	1 step < e.
Mar. 4:	= d.	11:	½ step < e.
16:	1 step > d.	12:	= e.
24:	2 steps > d.	15:	id.
29:	4 steps < c.	19:	1 step < d.
Apr. 16:	5 steps > d.	20:	½ step < d.
May 24:	2 steps < e.	23:	= e.
28:	id.	29:	½ step > e.
Aug. 16:	= f.	Oct. 2:	1 step > d.
18:	id.	4:	id.
22:	4 steps < e.	12:	= d.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 73, **12**, 56.

Nov. 10: 3 steps > d.
12: id.
14: id.
17: id.
Nov. 19: id.
Dec. 2: 5 steps > d.
6: 2 steps > d.
25: 4 steps < e.

T *Ursæ Majoris.*[2]

Jan. 17: T invisible.
Feb. 4: id.
17: id.
27: 5 steps < f.
Mar. 4: = f.
16: 2 steps < c.
24: 1 step > c.
29: id.
Apr. 16: = a.
May 24: 1 step > a.
28: = b.
Aug. 16: invisible.
18: id.
22: id.
24: id.
27: id.
31: id.
Sept. 6: id.
11: id.
12: id.
15: id.
19: id.
20: id.
23: id.
29: id.
Oct. 12: id.
Nov. 10: very faint.
12: id.
14: 3 steps < f.
17: 2 steps < e.
19: id.
Dec. 2: = c.
6: 1 step > b.
25: 4 steps > a.

W *Pegasi.*[1]

Jan. 17: W invisible.
Aug. 16: = c.
18: id.
21: < c.
> d.
24: 2 steps < c.
27: < c.
> d.
31: id.
Sept. 6: < d.
> e.
Sept. 11: < e.
> f.
12: id.
15: = f.
18: 1 step < f.
20: ½ step < f.
Nov. 10: = n.
19: < e.
> f.

SS *Cygni.*[1]

Jan. 17, 6^h: SS = b.
18, 6^h: 1 step > b.
May 24, 11^h: invisible.
Aug. 16, 10^h: = c.
18, 10^h: < c.
> d.
21, 10^h: 3 steps < c.
22, 10^h: id.
Aug. 24, 10^h: = c.
27, 9^h: = d.
31, 9^h: 2 steps > e.
Sept. 6, 8^h: = f.
11, 8^h: id.
12, 9^h: = g.
Nov. 10, 8^h: 2 steps > d.
14, 11^h: 2 steps > g.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 141, **24**, 109.

[2] Vide the sketch in the *Publications A. S. P.*, No. 22, **4**, 63.

U *Herculis*.[1]

May 24:	U = d.
28:	2 steps > d.
Aug. 16:	= h.
18:	id.
21:	2 steps < h.
24:	3 steps < h.
27:	id.
Aug. 31:	id.
Sept. 11:	5 steps < h.
12:	id.
15:	id.
20:	6 steps < h.
29:	id.

Var. 25, 1913, *Ursæ Majoris*.

(*f* = B. D. + 60° 1412 ($9^m.5$) = *f* in the sketch on T *Urs. Maj.*)

Jan. 17:	f ½ step > g.
Feb. 4:	> g.
27:	1 step > g.
Mar. 29:	= g.
Apr. 16:	2 steps > g.
Aug. 16:	½ step < g.
22:	2 steps < g.
24:	= g.
27:	1 step < g.
31.	= g.
Sept. 6:	id.
11:	½ step > g.
12:	1 step > g.
Sept. 15:	= g.
19:	2 steps < g.
20:	1 step > g.
23:	1 step < g.
29:	id.
Oct. 12:	1 step > g.
Nov. 10:	id.
12:	2 steps < g.
14:	½ step > g.
17:	= g.
Dec. 6:	1 step < g.
25:	id.

A SUSPECTED STAR.

(x = B. D. + 27° 3530 ($9^m.2$).)

While examining an old sketch of S. VULPECULÆ a year ago, I was surprised to see some undulations in the light of the little star *x* as compared with the following stars in that region:—

c = B. D. + 27° 3534 ($7^m.8$.)
f = 3532 ($8^m.8$.)
f′ = 3535 ($9^m.0$.)

I found *x* either brighter or fainter than f′, sometimes even *x* = *f*, which happened in 1914, November 10th.

Mr. VICTOR NIELSEN, "Urania," Copenhagen, has at my request had the kindness to observe and photograph the suspected star and writes about it: "The star *x* looks strange to me, and the photographic plates are apparently showing the star as an extraordinary object. Its color is, according to sev-

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[1] Vide the sketch in the *Publications A. S. P.*, No. 135, **23**, 42.

[illegible] observers, greenish." He has added the interesting remark: "When $x < f'$ visual, then $x > f'$ photographic, and x [illegible] nebulous and therefore difficult to get in focus."

Several other stars have been watched, such as Y *Tauri*, which on April 17th was 2 steps brighter, but on November [illegible] at least 4 steps fainter than the star B. D. + 20° 1095. [illegible] has been faint during this year. On March 24th and November 17th it was noted equal to its little companion-star, [illegible] April November it was at least 3 steps fainter.

LARGE METEORS.

[illegible] have been observed from stations in Denmark and surrounding countries on the following dates: January [illegible] 21st, February 12th (three observations), March 28th (eighteen observations from Denmark, one from Norway), [illegible] 21st, 24th (two observations), May 3d (two meteors), [illegible] (fourteen observations from Denmark and fifty from Sweden), August 5th (three observations), 13th (two meteors), November 10th, 17th, 25th (one observation from Denmark, three from Norway).

SHOOTING STARS.

[illegible] stars were observed from five stations in Denmark [illegible] Sweden from August 9 to 12, 1914. At these [illegible] paths of shooting stars were mapped, and [illegible] March 28th five proved suitable for calculation [illegible] meteors have given the following results:

[illegible]

From Calculation.

No.	Beginning.			Ending.			Real length of the path.	Radiant.	
	h	λ	φ	h	λ	φ	β	AR	Decl.
1	52.2	2° 39′.9 w	56° 5′.8	42.4	1° 57′.1 w	57° 13′.7	134	113°	÷27°
2				73	2 20.1 w	56 8.7			
3	114.4	1 18.0 w	55 31.1	111.4	1 43.3 w	55 13.1	43.6	69	+29
4	99.7	3 27.0 w	56 4.3	104.1	1 4.8 w	55 39.7	62	72	+22
5	66.9	2 15.9 w	55 20.1	62.4	2 33.6 w	55 13.9	23.4	54	+29
6				92	1 38.3 w	55 11.3			

h and β are expressed in kilometers; λ is longitude from Copenhagen; φ is north latitude; h is the altitude of the meteor above the Earth's surface.

The Carina-Meteor catalog has now reached the number of 5,944 meteors, observed from stations in Denmark and surrounding countries from 1875 to 1914 inclusive.

From August 10th to 15th, inclusive, astronomical lectures were held at the Carina Observatory in Odder.

In the estimation of variable stars I have been assisted by Mr. J. SKAKKE, who, also, by the aid of a 78^{mm} Darlot lens, has photographed numerous regions of the heavens. He likewise succeeded in obtaining a plate with several exposures of the Moon eclipse of March 12th, from $3^h\ 53^m$ to $5^h\ 33^m$ A. M.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1915.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter ..	May 5,	$9^h 23^m$ P.M.	Last Quarter ..	June 4,	$8^h 32^m$ A.M.
New Moon	" 13,	7 31 P.M.	New Moon ...	" 12,	10 57 A.M.
First Quarter ..	" 21,	8 50 P.M.	First Quarter.	" 20,	6 24 A.M.
Full Moon	" 28,	1 33 P.M.	Full Moon	" 26,	8 27 P.M.

The Sun reaches the summer solstice and summer begins on June 22d, about 4 A. M. Pacific time.

The present two-months period affords the best opportunity of the year for observation of *Mercury* as an evening star. It passes superior conjunction with the Sun on the morning of May 1st and the apparent distance of the bodies rapidly increases, so the planet remains above the horizon more than an hour after sunset some time before the middle of the month. Greatest east elongation 23° 18′ is reached on May 31st, and the planet then remains above the horizon nearly two hours after sunset. The planet and the Sun then begin to approach each other, but the interval between their times of setting does not lessen to an hour until about the middle of the month. After this the two bodies approach each other rapidly and come to conjunction on June 26th. There will therefore be a month or more in which the planet can be seen in the evening twilight. This is rather a long time for visibility. The greatest elongation, 23° 18′, is only an average one; but during May the planet is some degrees north of the Sun, thus retarding the setting of the planet. This condition is reversed in June, and the planet is somewhat south of the Sun, making a tendency toward an earlier setting; but the real distance of the planet from the Sun increases until June 20th, when aphelion is reached. This causes a less than average diminution of the apparent distance between the bodies after greatest elongation and retards the setting of the planet. Near the time of greatest elongation *Mercury* remains above the horizon long enuf so that twilight fades sufficiently to allow the brighter stars near the planet to be seen. The planet moves eastward thru the constellation *Taurus* and *Gemini*. Shortly after the first of May it is about 5° south of the *Pleiades*. On May 16th it is about 7° north of *Aldebaran*, *α Tauri*, the brightest star in the constellation. By June 1st it is on the border line between *Gemini* and *Taurus*. At the time when it ceases to be easily seen it is south and west (not far from vertically below, as seen near setting) of *Castor* and *Pollux* about 10°. On May 31st it passes conjunction with *Saturn*, the latter planet being 2° 29′ south.

Venus is a morning star, with gradually diminishing apparent distance from the Sun and diminishing brightness, altho it is still the brightest of the planets. Thruout the two-months period it rises about an hour and twenty minutes before sunrise, the interval not varying more than five minutes. It moves from the constellation *Pisces* thru *Aries* into *Taurus*, and on June 23d it will pass about 4° north of *Aldebaran*, *α Tauri*.

Mars is gradually drawing far enuf away from the Sun to be easily seen in the morning twilight. On May 1st it rises a little more than an hour before sunrise and on June 30th the interval has increased to about two and a half hours. During this time it moves 44° eastward and 15° northward from *Pisces* thru *Aries* into *Taurus*, reaching on June 30th a point about 5° south of the *Pleiades*. On the morning of May 14th it is in conjunction with *Venus*, the latter planet being about 1° south. *Mars* is still lessening its distance from the Earth, being at the end of June sixteen millions miles nearer us than it was on May 1st, and its brightness increases 10 per cent during the period, so that it is now about as bright as an average first-magnitude star.

Jupiter's apparent distance from the Sun is still increasing. On May 1st it rises about two hours before sunrise, and on June 30th it rises a little before midnight. It is in the constellation *Pisces*, moving about 8° eastward and 3° northward. At the end of June it is about 1° west and 2° south of the vernal equinoctial point, but will begin its retrograde motion before it reaches the equinox.

Saturn is in good position for evening observation during May, but is drawing nearer to the Sun and comes to conjunction on June 28th. On May 1st it sets nearly four hours after sunset; this diminishes to two hours before June 1st and becomes zero before the end of the month. It is in the western part of *Gemini* and moves about 8° eastward during the two months. On June 1st it is about half way between *Aldebaran* and *Castor* and *Pollux*. The rings retain their apparent opening, the minor axis being about 45 per cent of the major.

Uranus rises shortly before 2 A. M. on May 1st and shortly before 10 P. M. on June 30th. It is therefore getting far enuf away from the Sun to be seen on a clear moonless night, but unfortunately there is no bright star near. It is nearly stationary in the constellation *Capricorn*, moving about half a degree westward during June. There is a fourth-magnitude star, ι *Capricorni*, about 1° east during May and the distance between planet and star increases about one half during June.

Neptune is in the western sky in the evening, setting shortly before 9 P. M. on June 30th. It moves about 2° eastward in the constellation *Cancer*.

(EIGHTY-FIFTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded in duplicate to Mr. LEON CAMPBELL, Assistant in Charge of the Arequipa Station of the Harvard Observatory, in Peru, for the discovery of an unexpected comet on the morning of September 18, 1914; and to Mr. CHARLES JAMES WESTLAND, Christchurch, New Zealand, for the discovery of the same comet a few hours later.

Committee on Comet-Medal:

W. W. CAMPBELL,
R. H. TUCKER,
HEBER D. CURTIS.

NOTE.—The unusual difficulties in sending cable messages, arising from the world-wide war, prevented prompt announcements of the discovery of this comet to the observatories on other continents.

Mr. Campbell announced his discovery by cable promptly to Harvard College Observatory, the message was duly received, and the usual Harvard circular of information was issued on September 19th, but it was not practicable and probably not possible to inform European astronomers by cable thru the medium of the distribution bureau at Kiel, Germany. Mr. CAMPBELL discovered the comet at Greenwich mean time September $17^d.74$, and his first photograph of the comet was made at date September $17^d.80$.

Mr. WESTLAND'S discovery was made at Gr. M. T. September $17^d.99$, and he at once secured a photograph of the comet, which recorded a tail 10° in length. He promptly announced the discovery by telegraph to Mr. C. E. ADAMS, Government Astronomer, Wellington, New Zealand. Mr. Adams endeavored to cable to the Lick Observatory, but found that the British cable from New Zealand to British Columbia had been cut by an enemy's warship; whereupon he cabled the information to the Government Astronomer, Melbourne, Australia.

The comet was independently discovered by Dr. JOSEPH LUNT of the Royal Observatory, Cape of Good Hope. Dr. LUNT first saw the object at Gr. M. T. September $18^d.42$, but concluded that it was a nebula. The following night was cloudy. He first recognized that the object was a comet at Gr. M. T. September $20^d.27$, and the announcement of the discovery was cabled to London on September 21st. The Cape of Good Hope announcement was the first one to reach Great Britain.

The comet was also discovered independently by Mr. G. V. HUDSON, Wellington, New Zealand, and by Mr. A. BOALT, Napier, New Zealand, at Gr. M. T. September $18^d.90$.

All of the discoveries were made by naked eye, and it is probable that the object was discovered independently by still other observers.

The Comet-Medal Committee desires to record that each case of independent discovery by two or more observers must be considered on the basis of attending circumstances, and that the award described above is in no sense to be considered as establishing a precedent for future awards.

THE COMMITTEE.

STELLAR MOVEMENTS AND THE STRUCTURE OF THE UNIVERSE: REVIEW.[1]

By J. H. Moore.

The ultimate aim of all studies in stellar astronomy may be regarded as the solution of the problem of the constitution and structure of the universe; the determination of the relations existing between its members, and the nature and organization of this great system. Whether the investigations lie in the field of the accurate determination of star places, stellar parallax, the brightness of stars, radial velocities or are concerned with the classification of stellar spectra, their special interest, from the larger point of view, arises from the bearing of the results upon this problem.

During the past decade astronomical observations have accumulated at a rapid rate. Improved methods have resulted in greatly increased accuracy, and even the mere lapse of time has contributed its part in the determination of proper motions. One branch of astronomy can hardly be said to have attained to the age of majority, since it was less than twenty years ago that the spectroscopic method in the hands of Professor Campbell first yielded accurate values of radial velocity. To-day the velocities in the line of sight of some twelve hundred stars are available.

Improvements in photometric methods, especially thru the aid of photography, have given us more reliable data on the magnitudes of the fainter stars. Even in the counting of stars noteworthy advance has been made.

The data of observation have been subjected to statistical analysis by several investigators, and some very significant relations have been brought to light concerning the distribution and movements of the members of the stellar system as well as the general form of the system itself. To these researches Professor Eddington has made notable contributions. While in the solution of the problem only the first steps can be said to have been taken, nevertheless we are able to set down some results which seem fairly well established.

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[1] Macmillan Science Monographs. By Professor A. S. Eddington. Pp. XII + 266. London: Macmillan and Co. Ltd., 1914. Price, 6s net.

Professor EDDINGTON has taken the occasion in preparing the present monograph of presenting the results of his own researches and those of other investigators in a form which will appeal to those who have not been able to follow the more technical memoirs, without sacrificing any of the precision of these. It is a clear and connected statement of the present state of our knowledge, as developed within the past ten years, of the structure of the sidereal universe, and an account of the methods by which this knowledge has been gained. While suffering unavoidably from the lack of historical perspective incident to this form of treatment, it gains in the clear and precise statement of the problem and the direct and logical method of attack. The segregation of the mathematical development of star streams and the methods of statistical analysis in Chapter VII and X is a good arrangement for the general scientific reader, by whom these mathematical chapters may be omitted without marring greatly the continuity of the discussion. In the opinion of the reviewer it is also the arrangement to be preferred in the presentation of the subjects to students of astronomy.

The treatise is divided into twelve chapters. In the first the data of observation are considered,—apparent position in the sky, magnitude, type of spectrum and color, parallax, proper motion, radial velocity and in some rare cases the mass and density of a star. Before entering upon the discussion and application of these data the author presents in the following chapter a general view of the form of the sidereal system, the distribution of its members and the peculiarities of their motions, so that the reader may appreciate more readily the relation to the general problem of each investigation described in succeeding chapters.

It is probable that for some time and perhaps always, most of our knowledge concerning the distribution of the stars will have to be gained from the analysis of stellar magnitudes and motions from which, on the basis of certain hypotheses, the mean distance of star groups may be inferred. There is, however, a small number of stars which are near enuf to us to permit of accurate determinations of their parallaxes. As our information concerning these may be considered reliable and fairly complete, they form a good starting point from which to proceed in a study of the stellar system. In Chapter III Professor EDDINGTON gives a list of the nineteen nearest stars, whose parallaxes are equal to or greater than 0.″2 with a discussion of the extent to which this list is complete. It is perhaps surprising that the small sample should exhibit so faithfully many of the leading facts derived from more general studies. Eight of the nineteen stars are binaries, a proportion, however, which is somewhat higher than that given from statistics of spectroscopic and visual binaries. Even the phenomenon of star streaming is exhibited by them and the relative number of stars in the two streams is practically the same as that derived from the six thousand stars of Boss's Catalog. A striking peculiarity of stellar motion is indicated in that the least luminous stars appear to have a mean linear velocity much greater than that of the brighter ones. This point should be followed up in future investigations, for the indication is so clear as to lend some probability to its reality. A further significant feature is the relative number of stars of the spectral types within this sphere. There are none of Class B, two of Class A, eleven of Classes F, G, K, and four of Class M. Now this is not at all the relative proportions of the spectral classes represented by the stars to which the data of proper motion, radial velocities, counts of stars, etc., relate. In fact, as the author points out, these catalogs, owing to the method of selecting the stars down to a given apparent magnitude favor the stars of Classes B and A, since they are the more luminous. They, therefore, give us an incorrect view of the relative numbers of early and later type stars in any definite portion of space. A distribution of stars of different spectral types within a definite volume of space, similar to that shown above by the nearest stars, has been derived recently from a more general investigation by Professor SCHWARZSCHILD. The importance of taking into account this limitation in data derived from star catalogs when applying them to statistical investigations is noted by Professor EDDINGTON as well as in this later memoir.

The simplest type of stellar motion, that in which the members of a group are found to have equal and parallel motions, is considered in the following chapter. From a knowledge of the proper motions of the individuals of a moving cluster, together with the radial velocity of a single member, the parallax of the cluster is derived. Precise and detailed information is thus afforded of the distance and hence distribution and luminosity of stars whose parallaxes are beyond the limit of measure by the direct method. For two examples of the class, the *Taurus* and *Ursa Major* clusters, this information has been derived, but for the third, the *Perseus* cluster, the data at present do not permit a determination of the parallax.

These great communities of stars are known to be moving thru space in which are distributed many other stars not of their family, and yet the individuals of the cluster preserve their motions undisturbed. This fact, as the author very clearly points out, affords important evidence that the motions of stars are due to the central attraction of the whole stellar system rather than to the individual attraction of their neighbors.

A chapter is devoted to the results of recent investigations of the solar motion, with a brief outline of the theory of its determination from the observations. On account of its importance as a fundamental unit in researches on the distribution of the more distant stars, considerable attention has been given to the determination of the direction and speed of the Sun's motion. Two recent results, the one by Professor Boss, based upon proper motions, the other by Professor CAMPBELL, derived from radial velocities, have practically superseded the older values. The two results derived by fundamentally different methods agree very well in the position of the solar apex in right ascension, but for some unexplained reason the declination is some ten degrees lower for the apex determined from radial velocities.

The speed in kilometers per second of the Sun's motion is furnished in addition to its direction by the radial velocity method.

In Chapter VI the author gives a clear account of the two-stream theory, based largely upon his own researches. Here it is shown that the fundamental peculiarity of stellar motion, that of the tendency of the stars to move in two favored directions, is indicated by the proper motions of stars from all regions of the sky, and in a general way is confirmed by radial velocity observations. The direction and speed of the two streams, as well as the relative distribution of the stars between the two drifts, are deduced. From an investigation of the mean distances of the members of the two drifts, he concludes that the mixture of the stars in the streams is fairly complete. That the two-drift theory and the alternative point of view offered by SCHWARZSCHILD in his ellipsoidal hypothesis represent only the most striking features of the distribution, is clearly indicated by the author. HAHN's interpretation of the phenomenon in terms of the three-drift hypothesis is shown to furnish a closer approximation to the actual distribution. Attention is also called to the fact that the important property of drift O, in that it includes all of the members of a spectral class, seems to show that this drift corresponds to some real physical system.

The mathematical theory of the two-stream and ellipsoidal hypotheses and a comparison of the distributions resulting from the two methods of analysis are treated in the chapter which follows. The essential feature of both representations is the increase of peculiar velocities of the stars in two favored directions.

A most interesting chapter is given to the discussion of a series of remarkable phenomena which are associated with spectral type. The conclusion reached independently by KAPTEYN and CAMPBELL that the average linear velocity increases continuously with the type of spectrum from Class B to Class M constitutes one of the most significant discoveries in recent astronomy. On the usually accepted order of stellar evolution it appears as if a star is born without motion and gradually acquires one, and that this motion continually increases as the star grows older. The author considers the evidence in favor of some alternative explanations which attempt to correlate the phenomenon with mass or distance, and reaches the conclusion that it is a genuine correlation between speed and spectral type, independent of either mass or distance. From a study of the mean distances and distribution with reference to the galaxy of different spectral types, the conclusion is drawn that the stars of Class B are strongly condensed in the galactic plane; that the system of A stars is very oblate, while the system of M stars is almost globular. The hypothesis of dwarf and giant stars as put forward by Professors HERTZSPRUNG and RUSSELL is carefully considered. The order of evolution to which this hypothesis leads is directly opposed to the generally accepted one which, as the author says, "has been independently confirmed by studies of stellar velocities, galactic distribution, and the periods of binary stars."

In Chapter IX an account is given of the information to be gained by counting the stars brighter than a given magnitude. The value of this method depends largely upon the accuracy with which the magnitudes are determined to which the count refers. Great weight is given to the very comprehensive investigation of counts of stars between the second and seventeenth magnitude, published by CHAPMAN and MELLOTE in 1914. These results are made the basis of a determination of the relative extension of the stellar system in the galactic plane and in a direction perpendicular to it.

Our knowledge of the structure of the stellar universe could be said to be fairly complete if we were able to determine the laws of density, luminosity and velocity for this system. The author sketches very clearly the statistical methods whose object is the determination of these laws, based upon data of counts of stars between given magnitudes, mean parallactic motion of stars of given magnitudes, parallax determinations, and the distribution of the proper motions of stars brighter than a limiting magnitude. The elegant general solution of SCHWARZSCHILD for the determination of the density and luminosity law is presented, and the results of KAPTEYN and SEELIGER discussed. While, as the author notes, the numerical results will undoubtedly be modified later, these statistical researches have already advanced our knowledge of the distribution and luminosity of the stars and point the way for a further extension of it in the future.

A chapter is devoted to the description of the interesting phenomena of the Milky Way, star clusters and nebulæ. Attention is called to the remarkable distribution with reference to the galactic plane of clusters, of planetary and extended nebulæ, and of the spiral nebulæ. Concerning a subject about which so little is known as the spectra of spiral nebulæ, it is perhaps not strange to see the statement made that the spectrum of the *Andromeda* nebula contains bright lines. The presence of emission lines or bands in this nebula, according to an observation of WOLF, has not been confirmed by other investigators employing slit spectrographs. That bright lines or bands do occur in some other spiral nebulæ is well known, but the reviewer who has observed them is not ready to subscribe to the statement that they "are of the character of those found in some of the early type stars, and are distinct from the emission lines of the gaseous nebulæ." The author regards with favor, at least as a working hypothesis, the theory which regards these spiral nebulæ as "island universes." Favorable consideration is also given to the view which seems to be gradually taking shape, that our system of stars is a great spiral, and the tentative suggestion is made that "the two star streams and the double branched spirals arise from the same cause."

In the final chapter an account is given of an attempt to develop a dynamical theory of the stellar system, based on the principle "that the stars describe paths under the general attraction of the stellar system without interfering with one another." The application of dynamics to a system in which so little is known of the kinematical relations, has, as the author admits, been attended with very little success.

Professor EDDINGTON in his "Stellar Movements and the Structure of the Universe," has drawn for us the general outline and form of the stellar system, adding where possible the details of the arrangement and relations of its members. It is a truly remarkable and striking picture which he presents. Some of the details which have been sketched may later need to be modified or possibly erased; and undoubtedly others will be added. One cannot resist the impression that in some of its main features this picture is going to endure.

NOTES FROM PACIFIC COAST OBSERVATORIES.

NOTE ON THE RADIAL VELOCITIES OF SIX NEBULÆ IN THE MEGELLANIC CLOUDS.

The resources of the D. O. Mills Expedition to the southern hemisphere have in recent months been applied almost exclusively to the measurement of velocities of approach and recession of the nebulæ whose spectra contain isolated bright lines.

We have recently observed the one planetary nebula known to exist in the Smaller Magellanic Cloud. The mean of three observed radial velocities is about 160^{km} per second, recession. This high velocity would not in itself be surprising, for two or three planetary nebulæ in the northern sky have been found to possess still higher radial velocities.

Of the nineteen bright-line nebulæ known to exist in the Greater Magellanic Cloud, we have observed five. All of these have yielded radial velocities lying between the limits 250^{km} and 300^{km}, recession. These results are indeed surprising. It is scarcely possible to doubt that the one bright-line nebula cataloged and observed in the Lesser Magellanic Cloud, and the nineteen nebulæ cataloged, and the five observed, in the Greater Magellanic Cloud, are really within the structure of these Clouds, respectively. There are no other known bright-line nebulæ surrounding or at all near these Clouds. One must go many degrees toward the Milky Way before coming to other bright-line nebulæ.

A consideration of the high and nearly equal velocities obtained for the five nebulæ in the Greater Cloud suggests either that these nebulæ are to some degree associated with each other, traveling thru space certainly with nearly equal recessional velocities and possibly along nearly parallel lines, or that the nebulæ and the general structure of the Magellanic Cloud are traveling together. In particular, there is the question whether the Greater Cloud as a whole is receding from the solar system with a speed approximately equal to the average observed speed of the five nebulæ. Radial velocity observations of as many and as faint stars in the Greater Magellanic Cloud as available observing resources will permit are extremely desirable, and we hope to take up a limited program of observations of this kind, probably next year.

It has been suggested now and then that our stellar system if viewed from an exceedingly great distance might appear to be a spiral nebula, and conversely that the spiral nebulæ if observed close at hand might be seen as isolated stellar systems. The high apparent velocities of the Magellanic Clouds, especially of the Greater Cloud, are not out of harmony with the idea that they have little or no connection with our general stellar system. This condition might incline one to speculate upon the Magellanic Clouds as bearing some relation to spiral nebulæ, chiefly in view of the high average velocities which SLIPHER has recently found for many spirals.

RALPH E. WILSON.

SANTIAGO, CHILE, January, 1915.

NOTE ON COMET *a* 1915 (MELLISH).

The first comet of the present year was discovered by Mr. JOHN E. MELLISH, of Cottage Grove, Wisconsin, on February 10th. The telegram from the Harvard College Observatory announcing the discovery was received here on Thursday, February 11th, but clouds prevented observations until the following night. Measures were secured on February 12th and 13th (Mount Hamilton time), and then storms and, later, moonlight, made further measures impossible until February 26th.

As seen with the 12-inch telescope on February 12th, the comet appeared as a small, slightly oval object, about as bright as a tenth-magnitude star. The nucleus was well defined, tho not stellar, and measures of position were comparatively easy to make. By February 26th it had become perceptibly brighter, and was apparently a little larger.

On the basis of my first two measures and one by H. C. WILSON, of Carleton College Observatory, a preliminary orbit was computed at the Students' Observatory, Berkeley, by Professor CRAWFORD and Miss JESSICA YOUNG. This orbit was revised when the observation of February 26th was available. According to the improved elements, perhilion passage does not occur until July 20th, and the comet is approaching the Earth as well as the Sun, and will therefore increase in brightness very rapidly.

"The closest approach to the Earth will be about the middle of June, when its distance will be only a little more than four-tenths of an astronomical unit [i. e., about 40,000,000 miles]. At this time the brightness will be 165 times greater than at discovery. By the first of June the comet will be too far south to be seen from this latitude. It should be a very conspicuous object for those south of the equator during the month of June."

The comet is at present (March 15th) in the constellation *Ophiuchus*, about two degrees south of the fourth-magnitude star λ *Ophiuchi*, and is moving eastward and southward. On April 18th it will be on the border-line between the constellations *Serpens* and *Scutum*. R. G. AITKEN.

March 15, 1915.

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

COMPARISON BETWEEN THE DISTRIBUTION OF ENERGY IN THE SPECTRUM OF THE INTEGRATED LIGHT OF THE GLOBULAR CLUSTER MESSIER 3 AND OF NEIGHBORING STARS.[1]

This investigation is based on a spectrogram of the cluster secured with a prismatic camera of ultra-violet glass. The spectrum of the cluster, together with those of the simple stars with which it is compared, appear upon the same plate. In making the exposure the plate was allowed to drift, so that the stellar spectra are sensibly broadened, and are comparable with that of the cluster.

The comparisons were made by means of a Hartmann microphotometer, and the values of the density steps were determined from an objective grating plate by the well-known method of HERTZSPRUNG.

The observations, being photographic, are practically limited to that part of the spectrum to the violet of 5000 A; they are supplemented, however, by visual estimates of the difference in magnitude between the cluster and one of the comparison stars, the author assuming that the visual measures correspond to an effective wave-length of 5600 A. The differences in magnitude, in the sense cluster-star, for three wave-lengths are exhibited in the following table, based on a comparison of the cluster with four different stars:

Wave Length	Star	+ 27°2288	+ 28°2259	+ 28°2254	+ 28°2248
	Spectrum . . .	F_8	A_4	F_1	K_1
	Viz. Mag. Potsdam . . .	8.24	8.25	7.28	6.37
3761 A	. . . .	+0.14 mag.	−0.03 mag.	+1.01 mag.	−0.22 mag.
4555	. . . .	+0.09	−0.09	+0.96	+1.14
5600	. . . .	−0.63	−0.64	+0.33	+1.13

According to FATH, the spectrum of the star-cluster under consideration lies between A and G.

A remarkable feature of the cluster *Messier* 3 is exhibited in the table here reproduced, and also in the intensity curves which illustrate the paper. To the violet of 4555 A the light curve of the cluster closely approximates that of first three (early type) stars, while in the yellow the cluster is much stronger. The color index of the cluster seems to be somewhat greater than that of a star of the same spectral class. This appears to be a characteristic of the spectra of such clusters as have been observed.

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[1] By E. HERTZSPRUNG, *Astrophysical Journal*, 41, 10, 1915.

What strikes the reviewer as a weak point in such comparisons is the insufficiency of our knowledge of the so-called spectral class of the clusters, and indeed Professor HERTZSPRUNG remarks that the differences in relative intensity to which attention has been called, in the case of *Messier* 3, may be due to the possibly composite character of the integrated spectrum of the cluster. In addition he truly remarks that "in questions bearing on selective extinction of light in space the spectral class on one side and the distribution of energy on the other should at least be derived from an examination of the same region of the spectrum."

As the result of some experience in the observation of faint spectra the reviewer not only agrees with the view here expressed, but is inclined to go further. Clusters are, in general, so faint that, except in a few instances, our knowledge of the so-called spectral class of one of these objects rests upon observations of its integrated light made with spectroscopes of very weak dispersion. While such instruments as these may well serve to place the class of a simple spectrum, the spectrum that is of a single star, the determination of the prevailing class of a group of many stars is an accomplishment of an entirely different order and one beyond their power. On account of the great breadth of the hydrogen and other lines in the spectra of the so-called early stars, together with the relatively great strength of these spectra in the violet, the tendency would always be to place the spectrum of a mixed cluster too *early*, while the effect of the older stars in strengthening the yellow would be fully felt. It is very doubtful whether, with weak instruments, the matter would be improved by extending the observations for class over the visible part of the spectrum, since here the lines which are characteristic of the relatively old stars, say of Classes G or K, are comparatively narrow, and with low dispersion, to say nothing of the disturbing influence of superimposed spectra, would not record. The reviewer is therefore inclined to doubt the value of any assignment of class to the spectrum of a cluster, where such assignment is made on the basis of the integrated light of the object. Our only reliable guide in such matters seems to lie in observations of the character of those of PEASE, already referred to, of the spectra of individual stars, but unfortunately such observations are always difficult, and in many cases impossible, on account of the faintness of the objects.[1] W. H. WRIGHT.

March, 1915.

SPHERICAL ABERRATION IN ASTRONOMICAL OBJECTIVES DUE TO CHANGES OF TEMPERATURE.[2]

The 30-inch objective of the Thaw photographic refractor for the Alleghany Observatory was completed last summer by the JOHN A. BRASHEAR COMPANY, and installed in the tube and dome which had long been awaiting it. In the tests made in the optical shop, where the temperature conditions are under full control, the objective gave almost perfect definition, indicating that the glass in the lenses is of unusual excellence. The Thaw telescope has been in systematic use since last September.

When the objective was first tested in the telescope, by means of stellar images, it was found that the focal lengths of the outer zones were shorter than for the central and intermediate zones. Repeated tests showed that the amount of this aberration varied from night to night and even in the course of a single night. Professor SCHLESINGER'S analysis of the observed data indicated that the aberration is the effect of temperature and that it is greater when the temperature is falling rapidly, as for example, during the early hours of the night. He has devised interesting means for removing this temperature effect. The objective end of the telescope is enclosed during the day-time by a metallic cover which acts as a kind of temperature case. This device maintains thruout the day substantially the same temperatures in front of and behind the objective. This covering is removed about an hour before observing begins in the evening, and at the same time a small electric fan, mounted near the upper end of the telescope tube, is caused to blow a continuous current of air into the tube thru a large vent just below the rear surface of the objective. Two other similarly placed vents permit the air to escape from the tube. The effect is to cool the rear surface of the objective about as rapidly as the front surface is cooled by natural circulation of the air.

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[1] Mr. PEASE has photographed the spectra of nineteen separate stars in the cluster in *Hercules*, *Messier* 13. He finds all classes from A to G, Class F5 being the most numerous.—*Annual Report of the Director of the Mount Wilson Solar Observatory*, 1913, p. 219.

[2] Abstract of Professor SCHLESINGER'S article in *Proceedings of the National Academy of Sciences*, Vol. I, No. 1.

The front lens (flint) is separated from the rear lens (crown) by nearly half an inch. The metal cell which holds the two lenses in place is pierced by half a dozen holes one-half inch in diameter, at the edge of the air space which separates the two lenses. These permit the air to circulate between the two lenses.

The ventilating fan is placed in the circuit with the electric lights which illuminate the setting circles of the telescope. The observer naturally turns these lights on at the close of each photographic observation, for the purpose of finding the next object, and turns them off after the second object has been found. The fan is therefore in operation between successive exposures, thruout the night.

When the night's work is over the objective is covered with the metal temperature covering, and the three large and the three small openings in the tube are closed.

These devices have removed the aberrations due to differences of temperature in the lenses. When the temperature of the lenses and surrounding atmosphere is uniform, the figure of the objective as tested upon the stars has been found to be excellent. W. W. CAMPBELL.

A FAINT STAR WITH LARGE PROPER MOTION.

In *Astronomische Nachrichten*, 4775, Professor MAX WOLF gives an account of a star of the thirteenth magnitude (R. A. 1875.0 = $2^h\ 6^m\ 54.^s0$; Decl. + 15° 24′.4), which has an annual proper motion of about + 1.″1 in right ascension, the motion in [illegible] being very small. This remarkably large motion for [illegible] a star makes the discovery one of unusual interest, but [illegible] with it. Professor WOLF has made an observation, [illegible] so far as my knowledge goes, is unique. A star of the [illegible] magnitude was found on the earlier plates (about [illegible] north and east of the thirteenth magnitude star and [illegible]. The motion of the latter, in the following years, [illegible] directly across the line of sight to the former, causing an occultation that was almost central. In 1914 the fainter star was just discernible, emerging on the southwest limb of [illegible] of the proper motion star. R. G. AITKEN.

[illegible] 1915.

A NEW LINE IN THE SPECTRUM OF THE SOLAR CORONA.

The Spanish eclipse expedition to Crimea to observe the total [illegible] of August 21, 1914, consisted of Messrs. ASCARZA, CARRASCO and TINOCO.[1] The station selected was Theodosia, [illegible] north latitude. A Grubb coelostat, Rowland plane grating of 15,000 lines to an inch and an objective of 8cm aperture and 120cm focal length formed the spectrograph of Mr. [illegible] panchromatic and Wratten M plates were [illegible] is directed to a new coronal radiation dis[illegible] Mr. CARRASCO on a plate of 12 [illegible] exposure, [illegible] seconds after the second contact. [illegible] computed [illegible] of the new line measured with reference to Ha [illegible] 6378.7 [illegible] A.

[illegible] *Comptes Rendus* for December [illegible] 1914 Mr. [illegible] presents a communication by MM. [illegible] and [illegible] with reference to the results of the Meudon [illegible] expedition to Strömsund, Sweden. [illegible] plates shows that the [illegible] was perfectly [illegible] was observed [illegible] apparatus [illegible] The [illegible] given as [illegible] determined by [illegible] addition to the [illegible]

[illegible]

other coronal radiations, seems to be connected with the state of solar activity at the time of eclipses.

M. SELGA, S. J.

MOUNT HAMILTON, January 25, 1915.

SPECTRUM DIFFERENCES AND ABSOLUTE MAGNITUDES.

A recent investigation by Mr. W. S. ADAMS, of Mount Wilson, has shown that the intensity of the violet region relative to the red region is less in spectra of stars of small proper motion than in stars of large proper motion. This may be due to absorption in space or to difference in luminosity or absolute magnitude. In further study[1] he has derived evidence that spectral differences are due to stellar atmospheres and are possible criteria of absolute magnitude. Two groups of stars are investigated, one of small proper motions and one of large proper motions, each containing stars of the several classes from F to K. Two facts are immediately evident: The violet region is relatively weaker in the small proper-motion stars, and the difference increases with spectral class. The hydrogen lines are unusually strong in the small proper-motion stars and certain metallic lines systematically differ in intensity in the two groups of stars. The relative intensities of the violet and red regions were determined by comparisons under the Hartmann spectrocomparator with a series of different exposures on α *Tauri*, and all estimates for all the plates were reduced to a uniform series of densities. Since the difference between the violet and red increases with the type, and the ratio of the proper motions, assumed to indicate the ratio of distances, is nearly the same for each type, therefore more or less of the violet absorption must be due to stellar atmospheres. If the unusual strength of the hydrogen lines were due to hydrogen in space, the radial velocities from the hydrogen lines would differ from those given by metallic lines. But practically no difference is found, so that the hydrogen absorption must be in the stellar atmospheres.

A relation between changes in the line intensities and the absolute magnitudes is next sought for. Pairs of lines were selected, usually a hydrogen and a metallic line, and their relative intensities estimated on an arbitrary scale after the manner of the Argelander step-method for variable stars. After classifying the stars by the changes found, normal curves for each pair of lines were formed for each spectral class. The residuals from these curves were averaged for two groups of stars, those of low absolute magnitude and those of high absolute magnitude, these magnitudes being determined from the known parallaxes or from proper motion by means of KAPTEYN'S formula. Linear relations were then derived between these mean residuals and the absolute magnitude:

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[1] *Astrophysical Journal*, **40**, 385, 1914.

For Classes F8–G6, $M = +5.6 - 1.6D$.
For Classes G6–K9, $M = +6.8 - 1.8D$.

The relation is thus practically the same for all of the spectral classes. The magnitudes derived with these formulæ agree well with those derived from parallax or proper motion, the mean difference being only one and a half magnitudes. Spectrum differences therefore may possibly lead to determinations of absolute magnitudes. G. F. PADDOCK.

AN APPARENT PECULIARITY IN THE DISTRIBUTION OF PERIODS AMONG SPECTROSCOPIC BINARIES.

At the Observatory of Lund a catalog of statistics of spectroscopic binaries has been compiled.[1] It includes about 440 binaries. The periods of 88 are known and also of 16 binaries of the δ *Cephei* class. These 88 binaries have been divided into groups of Class B, Class A, classes F to K, and Class M. The distribution in each group with respect to the logarithm of the period shows a division of the binaries into two groups of different order of period; in other words, the frequency curves of each spectral group and of all combined show two maxima. Even tho the number of binaries is small and probably insufficient, the possibility of accounting for this apparent evidence of two orders of period is discussed.

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[1] *Meddelande fran Lunds Astronomiska Observatorium*, No. 63, 1914.

From the relation between the period, the semi-major axis, and the total mass, $P = \frac{a^{3/2}}{M^{1/2}}$, it is seen that the two orders of period might be accounted for by two orders of mass, or two orders of semi-major axis, or two orders of age of the systems, if the semi-major axis increases with time as suggested by DARWIN. It is not likely that two orders of age would explain the two orders of period in all the spectral classes separately. It is quite possible that there exist two orders of mass; altho the Cepheids which are thot to have small mass fall in the short period group, and the systems of longest periods have large amplitude of radial velocity, which is inconsistent with the relation $M :: K^3P$, which indicates that the amplitude K must be small in case of small mass. It is possible that two orders of mass would cause an analogous division of luminosities or of densities. A table of the frequencies of absolute magnitudes of these binaries based upon KAPTEYN'S list of parallaxes shows, however, that there is no division into two orders of magnitude. A table of frequencies of periods and the densities as published by SHAPLEY[1] for eclipsing variables, shows a slight indication of double grouping, that is, the long-period systems have small density. If this grouping is actual and if low density corresponds to small mass, this result favors the hypothesis of two orders of mass. But in eclipsing systems, especially those with large orbits, the components must have large size or volume and tho the density be small, the mass may still be great. Hence the data of eclipsing systems does not necessarily support the hypothesis of two orders of mass. In fact, there seems to be no real support for that hypothesis.

The remaining hypothesis of two orders of semi-major axis has the following point in its favor: Since the eccentricity increases with the period and the semi-major axis, there may exist two orders of eccentricity. A table of frequency of periods and eccentricities gives an indication of two orders or at least a discontinuity in the order of eccentricity. This evidence gives strong support to the hypothesis of two orders of semi-major axis. Explanation of it is not attempted, but it suggests two principles of generation, such as partition of mass for the short periods and capture of bodies in the case of long periods.

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[1] *Astrophysical Journal* **38**, 158, 1913.

Finally, it must not be forgotten that with an increasing number of computed binary orbits the grouping and division of the frequency curves may disappear.

G. F. PADDOCK.

THE RELATION BETWEEN PERIODS AND ECCENTRICITIES OF SPECTROSCOPIC BINARIES.

After a five-years' interval since Dr SCHLESINGER's discussion of spectroscopic binaries in 1910,[1] Mr. F. C. JORDAN, of the Allegheny Observatory, has collected all spectroscopic binary orbits for a second investigation of their periods and eccentricities.[2] At the former time there were 50 orbits, excluding Cepheid variables, while now there are 82 orbits, excluding those of binaries of the δ Cephei class. This represents an increase of 60 per cent in the number of published orbits and gives a good idea of the increasing interest and study of spectroscopic binaries. Mr JORDAN has divided the 82 systems into four spectral groups, containing respectively Classes [illegible] A to A5, F to F8, [illegible] to M. Each group is ar[illegible] of period, the range of which for the successive [illegible] days, one to 2175 days, [illegible] days [illegible]. The tabulation at once shows that although the [illegible] greater the greater the period [illegible] presents [illegible] days. Before and after these [illegible] the eccentricity does not increase with the [illegible] the [illegible]

[illegible]

of eccentricity, mentioned in the preceding note, on the apparent two orders of periods among spectroscopic binaries is thus well supported.

G. F. Paddock.

On Professor Turner's Theory of a Sun-Spot Swarm of Meteors Associated with Leonids: R. A. Sampson.

About a year ago[1] I gave an abstract of Professor H. H. Turner's novel theory to account for the sun-spots and the changes in their periodicity and noted that no critical comment on the theory had been published. Such a critical review is now given by Professor Sampson under the title quoted above.[2]

The first point advanced against the theory is that it would require us to attribute an improbable mass to the Leonids. On the assumption that the Leonids have a mass three times that of the Earth, it is shown that an "encounter" with a meteor swarm like the SSS (sun-spot swarm) at the distance of *Saturn* from the Sun would produce changes in the revolution period of the latter of the order of 1/10,000, whereas Turner's theory requires changes of the order of 1/10. To bring these fractions to equality would require a vast increase in the mass of the Leonids.

The second point of attack is directed upon "the encounter which the theory requires of *Saturn* with the Leonids at intervals of 9 revolutions of the former and 8 of the latter, that is to say, about 266 years." Professor Sampson bases his argument on a comparison of the best known orbit of the Leonid swarm and that of *Saturn* and concludes that there is no valid evidence of such encounters.

A most interesting feature of Professor Sampson's investigation relates to the date commonly assigned in text-books for the introduction of the Leonids themselves into our system by the action of the planet *Uranus*. This date is given as A. D. 126, upon the authority of Leverrier. It appears that Leverrier's work is not conclusive and that it is far more probable that the Leonids were thrown into their present orbit by the action of *Uranus* about A. D. 885. The fact that the first

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[1] See these Publications **26**, 110, 1914.

[2] Mon. Not. R. A. S. **75**, 82, 1914.

Leonid shower of which we have well attested records occurred in A. D. 902, lends strong support to this conclusion. Professor SAMPSON draws particular attention to this point, as an illustration of the danger of accepting a theory simply "upon the credit of a name."

It should be added that in the following number of the *Monthly Notices*,[2] Professor TURNER replies to Professor SAMPSON'S criticism of his theory. His argument, briefly, is that the latter "has omitted to take any account of the difference between a small compact planet and a large extended meteor-swarm." He thinks that such an extended swarm could produce the perturbations in the SSS called for by his theory without assigning to it any improbable mass.

As for Professor SAMPSON'S second point, he argues that the Leonids we know may be only a small part of the whole swarm; that the main swarm may have a slightly different orbit which would meet the conditions imposed by his theory, and, further, that the orbit of the Leonids, in general, is not nearly so well known as Professor SAMPSON assumes it to be. He adds, "I am well aware that this is only sketching possibilities instead of testing them, and that such sketches as I have given carry with them responsibilities to the discharge of which nothing has yet been done." His concluding paragraph gives the promise of further work upon the problem.

R. G. AITKEN

March 6, 1915.

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GENERAL NOTES.

The March, 1915, number of the *Popular Science Monthly* should prove of special interest to Western readers, in that it is entitled the "Pacific Coast Number," and is devoted entirely to articles in the various fields of scentific activity on Pacific Coast problems. Our members will find of particular interest a well-written and interesting article which heads the number,—"Astronomy on the Pacific Coast," by Professor R. T. CRAWFORD. Other papers of more than usual interest are "The Volcanic Activity of Lassen Peak, California," dealing with the recent eruptions, by Professor R. S. HOLWAY, and "The Last Wild Tribe of California," by Professor T. T. WATERMAN, treating of ISHI, the last of the Yana Indians, whose "discovery" in 1911 created such a furore among anthropologists.

A Second Harvard Map of the Sky.—As is well known, the Harvard College Observatory published several years ago a map of the entire sky, composed of photographic prints taken from negatives made at Cambridge and Arequipa with lenses of one inch aperture. Each chart was eight by ten inches in size, covered an area of 30° square, and the entire sky was covered by only fifty-five such charts. The limiting magnitude was about 11.5, and the total number of stars shown on the prints was about 1,683,000. In Circular No. 185 it is announced that a second series of similar charts is to be published; in this set, however, the centers of the plates coincide with the corners of the plates of the first series, it having been found that many fainter stars did not show at the corners of the large field employed because of distortion. The new set will be issued at a price of $15.

At the annual meeting of the Royal Astronomical Society, of London, a motion in favor of admitting women to membership was adopted by a nearly unanimous vote. It is stated in

Nature that a supplementary charter will now be applied for to permit this resolution to be put into effect.

Among recent medal awards to astronomers is that of the Rumford Medal of the American Academy of Science (Boston) to Professor Joel Stebbins, for his application of the selenium cell to the study of light variations in stars; and that of the Gold Medal of the Royal Astronomical Society to Professor Alfred Fowler for his spectroscopic researches.

We regret to record the death, on January 24, 1915, of Dr. Arthur Auwers, at the age of 76. Dr. Auwers, for many years before his death, was known as one of the foremost astronomers of his generation, and was accorded many honors. He was the second Bruce Medalist of our Society, receiving the award in 1899. A brief account of his work to that date will be found in No. 67 of these Publications.[1]

Observers interested in watching for meteors and in recording their paths will find a convenient set of star maps in the current number of the *Journal* of the Royal Astronomical Society of Canada.[2] The maps, constructed by Dr. Reynold K. Young, of the Dominion Observatory, are on the gnomic or central projection, so that great circles of the celestial sphere appear as straight lines on the maps, and cover the sky from the North Pole to — 30° declination.

Since its beginning, in 1907, the *Journal* of the Royal Astronomical Society of Canada, has been published as a bi-monthly, but, in the November-December, 1914, number, Dr. C. A. Chant, the editor, announced that in future it would appear monthly, omitting, however, two summer months. The change, affording more frequent and prompt publication, is of obvious advantage, and it is to be hoped that the plan will prove a success.

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[1] **11**, 61, 1899.
[2] **9**. 7. 1915.

M. ROBERT JONCKHEERE, Director of the Observatory of the University of Lille, France, is at present at the Royal Observatory, Greenwich, England, and requests that publications intended for him be sent to this address.

Note on the International Latitude Service.—From a letter recently received from Dr. ALBRECHT, of the International Geodetic Association at Potsdam, it is learned that notwithstanding the war, observations for variation of latitude will be continued during the year 1915 at all of the stations except Gaithersburg, Md.

The observation books from Japan, Dr. ALBRECHT says, have thus far been received regularly. There is an interruption in the receipt of the books from Tschardjui, but not in the series of observations.

It is gratifying to know that the warring nations can still co-operate to some extent at least in scientific work.—J. G. PORTER (in *Popular Astronomy*, March, 1915).

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT CHABOT OBSERVATORY, ON SATURDAY, MARCH 27, 1915, AT 7:30 P. M.

There were present President **AITKEN** and Directors **BURCKHALTER**, **COSTA**, **CORNISH** and **RICHARDSON**.

The following were elected members of the Society:

Rev. CLARENCE E. WOODMAN, Sc.D., Ph.D., Litt.D., LL.D.
Mr. EARL C. LINSLEY.
Mr. A. T. BOLFING.

After some remarks by the President relative to the participation of the Society in a joint session with the American Astronomical Society in this city, in August next, a resolution was passed, placing full power in the hands of the President to make such arrangements and prepare such programs as he judged proper.

Adjourned.

D. S. RICHARDSON,
Secretary.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT CHABOT OBSERVATORY, OAKLAND, ON SATURDAY, MARCH 27, 1915, AT 8:00 P. M.

The cosy little Assembly Hall of the Chabot Observatory was placed at the disposition of the Society for this meeting, through the courtesy of the Oakland School Department, and a small but very attentive audience gathered to hear Dr. R. G. AITKEN's lecture on "Star Clusters." The subject was beautifully illustrated and deftly handled by the speaker, than whom it were hard to find a scientist who can get closer to the minds and sympathies of a layman's audience.

Mr CHARLES BURCKHALTER prefaced the lecture of the evening by a report on the progress of his new observatory and twenty-inch glass, and all friends of the science will be glad to know that the School Department of the city of Oakland will have a fully equipped astronomical department in full working order within the coming year.

D. S. RICHARDSON,
Secretary.

OFFICERS OF THE SOCIETY

Mr. R. G. Aitken .... *President*
Mr. S. D. Townley .... *First Vice-President*
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NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished free of cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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ASTRONOMICAL EXHIBITS AT THE EXPOSITION.

By HEBER D. CURTIS.

Those interested in astronomical science will find a number of very interesting displays at the Panama-Pacific International Exposition. The *piece de resistance* is doubtless the 20-inch equatorial for the Chabot Observatory, exhibited by WARNER & SWASEY in one of the main aisles of the Liberal Arts Building. This is a beautiful piece of work and attracts a good deal of attention.

The design of this telescope is on the same general lines as the well-known larger instruments of this firm. A ball thrust at the lower, and a live ring of steel rolls at the upper end of the polar axis relieve the friction of this portion of the instrument: the slow motion in right ascension is of the sector type as in all of the recent instruments made by this firm. This motion on the 36-inch refractor of the Lick Observatory is connected with the polar axis gearing so as to furnish a slow motion which is continuous and never "runs out;" with the sector type the necessity will occasionally arise to run the sector back to a middle position, but this drawback is more than counterbalanced by the greater cheapness, simplicity, and freedom from backlash given by the sector type of motion. Contact rings are built into the instrument on both the polar and declination axes to carry the illumination currents; the clock may be wound either by a small electric motor or by hand, and a clever arrangement of planet gears makes it possible to use either method without making any changes whatever. The telescope is equipped with two finders and with right-ascension setting circles mounted on the front of the pier, with a hand wheel for moving in right ascension. The driving clock is of the usual type, provided with a very clever and compact device for giving either sidereal or lunar rate. The telescope is provided with the traditional finely divided silver circles as well as the coarser setting circles which are all that are ever used in practice. The fine circles are employed solely, now-a-days, to get the accurate adjustment of the axes when the instrument is first set up, and after that are forgotten. Since the 36-inch refractor was erected I believe that the only time these fine circles have been really used was after the earthquake, to test whether the instrument was still in adjustment. All the necessary adjustments of an equatorial can be quickly made by photographs of the pole; several large reflectors, among them the Crossley and the 37-inch Mills reflector at Santiago, are totally unprovided with fine circles, and the same is true of the 30-inch photographic refractor of the Allegheny Observatory. The cost of finely divided circles is high, and one questions whether it would not be better to depend entirely on photographic methods for adjusting the polar axis and put the money thus saved into subsidiary apparatus.

WARNER & SWASEY also exhibit a fine 9-inch equatorial, and a 4-inch combined transit and zenith telescope with a number of interesting points. This instrument is provided with two latitude levels, one of which is attached permanently to the latitude vernier. The striding level is left permanently in place, with a device for relieving the pivots from its weight when not in use. They exhibit also a 2-inch altazimuth whose microscopes are provided with four filar micrometers; the circles and the latitude and striding levels read to one second of arc. A chronograph of standard pattern is shown, and the micrometer of the 20-inch equatorial. This micrometer is provided with two rapid motions in position-angle of the milled head and pinion type; one motion has twice the speed of the other. Photographs of the main instruments made by this firm are attractively displayed, as well as drawings of the great Canadian and Argentine reflector mountings, now in process of construction. A complete working model of the 72-inch Canadian reflector and dome will soon be added to the exhibit.

BRASHEAR'S exhibit is combined with that of WARNER &

SWASEY. Here are shown a full size reproduction of the 72-inch disk for the Canadian reflector and a fine collection of prisms and lenses of various types, including a 15-inch lens. Several fine gratings of fifteen thousand lines to the inch are also shown; the largest of these has a ruled surface 3.75 by 6.19 inches.

The astronomer will also find a number of points of interest in the very complete exhibits of surveying and other scientific instruments made by such firms as KEUFFEL & ESSER, BAUSCH & LOMB, LIETZ & Co., W. and L. E. GURLEY and others.

Besides an unusually complete and extensive assortment of surveying and geodetic instruments, KEUFFEL & ESSER exhibit several interesting periscopes and a Coast and Geodetic Survey tide-gauge. One should not miss, also, a novel sextant which they have on exhibition. The arc of this sextant is divided only into full degrees and there is no vernier. Instead the limb of the sextant is cut with very accurate worm teeth, into which meshes a worm moving with the arm of the sextant and provided with a divided head. A simple and handy little lever moves this worm into or out of mesh. In use, the arm is moved rapidly to the approximate position just as with an ordinary sextant, and when nearly in the correct place, instead of clamping the arm, the worm gear is dropped into mesh and the divided head turned till proper coincidence of Sun's limb and horizon is obtained. Then the reading of the sextant is given at once; the full degrees being read from the circle and the minutes and fifteen-second intervals from the divided head. It is much quicker and easier to read than an ordinary vernier. All depends, of course, on the accurate cutting of the worm teeth of the sextant limb, and only a series of tests can show whether the instrument would keep the accuracy required in use; accumulation of dust in the worm teeth might render it less accurate than a divided circle. Another convenience on this sextant is a small dry battery concealed in the sextant handle; from this battery a small bulb may be lighted by a button under the observer's thumb so as to illuminate the limb and the divided head for a reading. The same firm shows a ship's telescope with a finder of unusual interest. The telescope itself is provided with a neat device for changing the magnification from fifteen to forty-five without changing eyepieces or altering focus. Several years ago Professor TODD devised a finder for astronomical telescopes so fitted with right-angle prisms that the finder eyepiece could be placed close to the eyepiece of the main instrument. With a large instrument the finder eyepiece is two or three feet away in the ordinary form, and for some classes of astronomical work, e. g., double star work, where there must be constant intercomparison of finder and main telescope field, this distance between the two eyepieces entails, in the aggregate, a great deal of work. The finder of the ship telescope is a "broken" finder with two right-angled prisms, as in Professor TODD's scheme, but the eyepiece used for the finder is that of the main telescope, one of the right-angled prisms being fitted *inside the main tube* so that it can be quickly moved into or out of position in the axis of the main telescope by a light lever. By manipulating this lever, without moving the eye from the eyepiece, one can instantly change back and forth from finder to main field and *vice versa.*

Besides an excellent display of projection apparatus and microscopes, BAUSCH & LOMB exhibit several range finders, from small portable types up to a large one with a base line of twelve feet. They show also an 8-inch circle meridian theodolite and a 4-inch equatorial telescope. There is also a very large position micrometer with a number of special features. Besides the ordinary rapid longitudinal motion of the ocular a cross motion is provided as well. Clamps are provided for the various divided heads on the measuring screw. There seems to be no rapid motion for rotating the micrometer in position angle, and the slow motion for this is not very conveniently arranged. As a matter of fact, a slow motion for position angle in a micrometer is deemed unnecessary by practiced observers to-day, and that on the 36-inch micrometer has long been discarded. The micrometer is a beautiful piece of work, mechanically, but the simpler such a piece of apparatus can be made the better, and most practical astronomers would regard this piece of apparatus as too complicated.

Quite a number of adding and calculating machines are exhibited by various firms, and the astronomer will find this a very favorable opportunity to compare the different types.

Aside from the instruments mentioned which deal with the mechanical aspects of the science, there is but one purely astronomical exhibit at the Exposition, that of the Carnegie Institution. This is located in the Education Building, and no astronomer should miss seeing the beautiful exhibits shown here of the astronometric work done at Dudley Observatory and of the various fields covered by the activities of the Solar Observatory on Mt. Wilson.

The Lick Observatory has no exhibit at the Exposition, the Regents having decided that no exhibit should be made by any of the departments of the University of California, the nearness of the University to the Exposition making it its own exhibit.

The exhibit of the Dudley Observatory comprises a model of the *Taurus* cluster, photographs of the southern station at San Luis, Argentina, and a set of photographs and transparencies illustrating star-streaming, absorption of light in space, and kindred phenomena. The Mt. Wilson exhibit comprises a large set of excellent photographs displayed in swinging frames which show all the buildings and the more important instruments and pieces of special apparatus at Pasadena and Mt. Wilson. In addition a complete set of illuminated transparencies show the more important results secured in the spectroscopy of the Sun, sun-spots, stars and nebulæ and a splendid series of enlargements of photographs of nebulæ and clusters made with the 5-foot reflector. All in all, the exhibit is one before which everyone, astronomer or layman, will linger long and to which he will return again and again.

STELLAR RADIOMETRY.

By Keivin Burns.

Dr. W. W. Coblentz[1] has recently put a new instrument at the disposal of astronomers. Besides a description of this instrument, the article referred to above contains a list of over a hundred stars whose total energy was measured by Dr. Coblentz. It is the purpose of the present note to compare the total energy with the visual and photographic magnitudes of these stars; to compare the spectral energy distribution with that of a black body, and to make some suggestions as to further work with the radiometer. Dr. Coblentz wishes me to emphasize at the outset the fact that his work was that of a pioneer, designed rather to show that positive results could be obtained than to make the most accurate measurement on a group of stars. The installation was merely temporary and few stars were observed more than once each.

In making the following tables, I have omitted α *Virginis* on account of its being observed near the horizon; α *Arietis* was omitted on account of suspected faulty classification; and α *Herculis* seems to be in a class by itself.

The results obtained by means of the radiometer are expressed in terms of the galvanometer deflection, the numbers being proportional to the total energy less atmospheric absorption. The deflections were translated into magnitudes to facilitate comparison with the visual and photographic data at hand. The radiometric minus the visual magnitude, and the radiometric minus the photographic magnitude was found for each star, and the mean taken for each spectral class. (I shall refer to these data hereafter as rad.-vis. and rad.-phot.) The data found in Harvard Revised Photometry[2] was used for the visual and photographic magnitudes. It is to be noted that the photographic magnitude as here given is based on the intensity of the spectrum at the G line, λ 4320A.

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[1] *Lick Observatory Bulletin*, **8**, 104, and *Bulletin Bur. Stand.*, **11**, 613.

[2] *Harvard Annals*, 50.

TABLE I.

Comparison of Radiometric with Visual and Photographic Magnitudes.

Class.	Limits.	Rad.-Vis.	No.	p. e.	Rad.-Phot.	No.	p. e.
B1	B-B2	−0.30	8	.08	−0.89	6	.13
B4	B3-B5	−0.40	4	.18	−0.6	2	..
A	B8-A2	−0.28	22	.04	−0.75	10	.10
A5	A3-A5	−0.21	5	.07	−0.83	4	.06
F	F	−0.8	1	..	−1.4	1	..
F5	F5	−0.5	2	..	−1.2	1	..
G	F8-G	−0.96	12	.09	−2.02	10	.10
G5	G5	−1.2	2	..	−2.1	1	..
K	K-K2	−1.12	21	.06	−2.46	21	.09
K5	K5	−1.69	5	.16	−3.69	5	.25
Ma	Ma	−2.20	10	.06	−3.70	8	.14
Mb	Mb	−2.7	2	..	−4.7	1	..
N	N	−3.2	1	..	......	..	..
α Herc	Mb	−4.2	..	..	−5.8	..	..

A glance at the column headed rad.-vis. shows that there is a tendency toward a maximum at class A5, and that the so-called earlier classes do not differ so very much in this datum. In fact, the rad.-vis. is the same, within the limits of error, for the classes B1 to A5. Only three stars of a class between A5 and F8 were observed. The total intensity of class G and K stars is twice that of class B and A stars of the same visual magnitude, and this ratio increases with advancing age until class N stars are fifteen times as rich in energy as class A stars of the same visual brightness, and α *Herculis* is relatively weaker still in visible rays. It is interesting to note that within the errors of observation stars of class K do not differ from those of class G in the ratio of visible to total energy. This is in agreement with the classification of Sir NORMAN LOCKYER, in which stars of classes G and K are put together. It is evident from the values of rad.-phot. that the spectra of these classes have a different energy distribution, and this may also be easily seen from a study of the photographic spectra. From K to K5, K5 to Ma, Ma to Mb and Mb to N there is a progression of striking regularity in the value of rad.-vis. If our eyes had the same sensitivity curve as the radiometer, *Antares* would be the brightest star in the summer sky, and *Betelgeux* the brightest one observed by Dr. COBLENTZ; the latter is no doubt nearly the equal of

Sirius in total intensity. The comparison of the intensity of the stellar spectra at λ 4320A with the total energy (Table I, column 6) shows that the ratio of these quantities is the same within the limits of error for stars of classes B to A5. This result was not expected as the work of KING, PARKHURST and others has conclusively shown that class B stars are brighter photographically than stars of class A of the same visual magnitude. However, in determining the photographic magnitudes these investigators used the integrated photographic intensity, and the data of Table I refers to the intensity at a given point in the spectrum. From A5 to Mb the photographic intensity falls off irregularly and, as is well known, very rapidly. Thus *β Pegasi* and *α Herculis* (class Mb) are respectively 35 and 100 times as rich in total energy as a star of class B or A of the some photographic magnitude.

When the stars are grouped according to class, it is seen that the values of rad.- vis. agree to within a few tenths of a magnitude in most cases. This is true even of the observations of the very faint stars, where the galvanometer swing is less than a millimeter, showing that the faint stars can be observed with considerable accuracy. Of the eleven stars which were observed more than once, only two depart more than two-tenths of a magnitude from the mean rad.-vis. for their class. It is likely that, whenever the departure is as much as three or four-tenths of a magnitude, the star in question will be found to have an energy curve differing from the mean for its class *β Ophiuchi* was observed twice and it appears to be half a magnitude weaker in total energy than other class K stars of the same visual magnitude. *α Herculis,* class Mb, was observed several times and it was found to be abnormally strong radiometrically, the value of rad.-vis. being greater for this star than for 19-*Piscium*, class N.

Double Stars.—Four faint companions were measured, all of which have been called "blue." The color is not borne out by the radiometric observations, as the rad.-vis. is in every case the same as that of the primary within the limits of observation. Of thirty-nine isolated stars of class B to A5, only one had rad.-vis. as large negatively as the smallest value for a companion star given in this table.

TABLE II.

Rad.-Vis. for Double Stars.

Name.	Star A. Class.	Star A. Rad.-Vis.	Star B. Class.	Star B. Rad.-Vis.	Separation.	Notes.
γ *Andromedæ*	Kp	−1.4	A	−1.4	10″	B is double Common P.M.
β *Scorpii*	B1	−0.4	"Blue"	−1.0±	14″	A is double Common P.M.
α *Herculis*	Mb	−4.2±	"Blue"	−4.5	4″.6	Common P.M.
β *Cygni*	Kp	−1.2	B9	−1.3	34″	Common P.M.

In the case of α *Herculis*, irradiation from the primary may have caused the secondary to be measured too strong; this is not likely to have been the case with the other stars,—it could not have happened in the case of β *Cygni*. These early class and "blue" companions appear to be relatively strong in total energy. It will be a very useful piece of work to investigate double stars radiometrically, even tho close pairs cannot be observed.

Parallax and Absolute Magnitude.—The absolute total intensity was computed for those stars for which the parallax has been observed. As there were only twenty of these, the statistics are not of much value. Among these stars there is no tendency for one class to be more intense than another. The rad.-vis. is not a function of absolute intensity. When rad.-vis. is plotted against parallax it appears that the more distant stars are somewhat weaker visually than are the closer stars, but more data will be necessary in order to be certain of this. The photographic data for the parallax stars is lacking.

Comparison of Transmission thru Water with Rad.-Vis.—The percentage of transmission thru a water cell is given by Dr. COBLENTZ for a few stars of the classes B8 to Mb. When these percentages are plotted against rad.-vis., the points fall close to a smooth curve if we use the rad.-vis. for the individual stars. This curve has a sharp bend at 69 per cent, class A5. If, instead of using the rad.-vis. for the individual stars, we use the mean for the class, the points do not fit a curve. This strengthens the view, expressed above, that the energy distribution in individual stars may depart quite widely from the mean distribution for a class.

PLANCK'S *Distribution Law and Temperature.*—PLANCK'S law of the distribution of energy in the spectrum of a luminour body $E_\lambda = C_1 \frac{1}{\lambda^5 \left(e^{\frac{C_2}{\lambda T}} - 1\right)}$, has been used by several investigators, notably by WILSING and SCHEINER, to estimate the temperatures of the stars. It is evident that most stars do not follow this, nor any other simple law of distribution, exactly. For the stars of early and late types have strong emission lines, or strong absorption bands or both. Furthermore, there is no certainty that the radiation from any substance will follow PLANCK's law at temperatures far above that at which the substance becomes a gas. However, some of the stars have energy curves which so far as we know follow this law at least roughly, and it will be of interest to see for what classes of stars the law is entirely inapplicable. Accordingly, the distribution curves were plotted for temperatures ranging from 2000° to 9000° Abs., and these curves were corrected for atmospheric absorption. The visibility of each corrected curve has been found, the intensity at the G line, and the percentage of transmission thru 1^{cm}. of water in a quartz cell such as was used by Dr. COBLENTZ. Table III gives the atmospheric transmission which was used; the values were derived from the results contained in *Publications of the Smithsonian Astrophysical Observatory*, Vol. III. I aimed to find the transmission for Mt. Hamilton, where Dr. COBLENTZ made his measurements. For the work done with the water cell furnishes the most important data which we have relating to spectral energy distribution of the stars. Furthermore, no permissible values of the atmospheric transmission in different parts of the spectrum would have any great effect on the ratio of total energy to visibility, and the effect on the relation between total energy and intensity at 4320A would not be very great. Table III also contains the values which were used for the sensitivity of the eye to various wavelengths, and the transmission thru a water cell 1^{cm}. thick.

TABLE III.

Percentage of Transmission and Visibility at Various Wave-Lengths.

Medium \ λ in 100A	30	35	40	45	50	55	60	65	70	80	90	100	110	120	130	140	200	300
Atmosphere	0	50	63	72	79	81	84	86	89	90	92	94	94	94	94	94	93	93
Water	80	85	85	85	85	85	85	85	80	75	70	50	30	15	10	0	0	0
Visibility	0	0	4	8	34	100	63	11	1	0	..	..	..	..	..	..	..	..

Denoting by 100 the intensity of the energy which would penetrate the atmosphere, the value of the energy outside the atmosphere is given in Table IV for a black body ranging in temperatures from 2000° to 9000°. The line opposite "water" gives the percentage of the energy penetrating the atmosphere which would be transmitted by the water cell. Opposite "visibility" are found numbers which give the ratio of the visibility to the total energy. To get these numbers I multiplied the ordinates in the black body curve (as transmitted thru the atmosphere) by the percentages opposite "visibility" in Table III, and then took the ratio of the area under the resulting curve to that under the curve before the ordinates were reduced. Opposite "λ 432" are found numbers expressing the intensity at the G line on an arbitrary scale.

TABLE IV.

Data from Black Body Curves.

Temperature	2000°	3000°	4000°	5000°	6000°	7000°	8000°	9000°
Outside atmosphere	110	110	111	117	125	140	160	185
Water	8	26	40	51	58	67	72	74
Visibility	0	2.7	7.7	12	15	17	19	20
λ 432	0	1.0	4.8	12	17	20	22	24

Considering Table IV we find that if we had stars of all temperatures whose spectral energy curves obeyed PLANCK's law we could readily measure the temperatures by means of the transmission thru water until we reached the temperature 8000°. After this temperature the estimates would be indeterminate, as the water transmission varies but little and approaches 75 per cent. Again, if we knew the temperature of one of the stars, we could compute the temperatures from the visibilities, but here also the values would be indeterminate for the higher temperatures. What is true of the visibilities applies also to the photographic intensities. The temperatures computed in the three ways would agree, of course. The indeterminateness at high temperatures is brought about by the absorption in the atmosphere. Comparing columns 3 and 6 of Table I with lines 4 and 5 of Table IV we see that we are dealing with similar curves. This leads us to suppose that we may be able to relate the rad.-vis. and rad.-phot. with the temperatures of a black body. We shall see that the data collected by Dr. Coblentz shows that this cannot be done, as the required water transmission is greater than that which was observed in the case of the early type stars.

For each of the stars whose energy transmission thru water has been measured, Table V gives this transmission in per cent., the rad.-vis., and rad.-phot. The last datum is for the individual stars in the case of *β Pegasi* and *α Herculis*, but for the other stars the mean value for the class was used. The temperatures computed from the water transmission is given in the sixth column. The seventh and eighth columns contain the temperatures computed from rad.-vis. and rad.-phot., assuming that the early type stars have a temperature of 8000°.

TABLE V.

Transmission and Intensity Ratios.

Star	Class.	% Transmission H_2O.	Rad.-Vis.	Rad.-Phot.	Temperature		
					H_2O Trans.	Rad.-Vis.	Rad-Phot.
β Orionis	B8p	42	0.0	—0.8	4200	....	8000
α Lyræ	A	58	—0.2	—0.8	6000	8000	8000
α Aquilæ	A5	69	—0.2	—0.8	7400	8000	8000
α Aurigæ	G	48	—0.9	—2.0	4700	4700	4300
α Bootis	K	45	—1.2	—2.5	4500	4000	4000
α Tauri	K5	35	—1.9	—3.7	3700	3300	3200
γ Draconis	K5	32	—1.7	—3.7	3500	3400	3200
α Orionis	Ma	27	—2.8	—3.7	3100	2600	3200
α Scorpii	Map	27	—2.4	—3.7	3100	2900	3200
β Pegasi	Mb	29	—2.5	—4.9	3200	2800	2600
α Herculis	Mb	21	—4.0	—5.8	2700	2200	2400

The limit of error in temperature computed from water transmission is 200° or 300°, excepting in the case of *α Aquilæ*. The intensity of this star is so low and the transmission is so high that the temperature determination may be in error by + 500° or — 1000°. The value of the transmission thru water gives the temperature (Table V, column 6), by comparing this value with the line "water," Table IV, supposing the star's spectral energy curve to follow Planck's law. It may be a surprise to many astrophysicists to find *α Lyræ* and *β Orionis* at a lower temperature than *α Aquilæ*. The very low value of *β Orionis* is perhaps peculiar to that star. The class G Star, *α Aurigæ*, appears to be at a lower temperature than we should suppose from considering the Sun to be over

6000°. The highest value of the temperature which it is possible to assume for α *Aquilæ* and α *Lyræ* in view of the water transmission is 8000°; assuming this value, the temperatures of the other stars was computed by comparing the black body visibility (Table IV) with rad.-vis., Table V, column 4. This gives an impossible value for β *Orionis,* and for the other stars, values which are sometimes lower than those computed from the water transmission. If we assume α *Bootis* to be at a temperature of 4500°, the values from rad.-vis. for stars of class B and A become impossible, but stars of classes later than F would then have temperatures agreeing very well with those found from the water transmission. If, instead of using the values of rad.-vis. for the individual stars, we use the mean for the class, the temperature of β *Orionis* becomes 7500° instead of being impossible, the temperature of α *Orionis* becomes 3000° and the other stars are not appreciably affected. Comparison of the line "λ 432" of Table IV with column 5 of Table V shows that what has been said of temperature estimates from rad.-vis. is true of similar determinations from rad.-phot. In other words, the data for stars of classes G to Mb are consistent with the assumption that the spectral energy distribution follows PLANCK's law roughly. But on this assumption the stars of classes B and A do not follow this law at all. For this reason it is impossible to invoke this law to prove that early type stars are hotter than those of later type. Again, if the blue stars follow PLANCK's law, their temperatures must be rather low, as shown by the water transmission, and so the late classes cannot follow the law at all. I prefer to think that the stars of late type follow this law the more closely.

A comparison with the temperatures published by WILSING and SCHEINER shows good agreement for classes G and later, but these investigators assign much higher temperatures to stars of classes B and A than are compatible with the observed water transmission.

In undertaking an extended research along radiometric lines, it will be necessary to determine the atmospheric transmission curve for the ultra-violet, as well as for the visible and the infra-red. And, of course, it will be necessary to measure the atmospheric transmission, at least for some points in the spectrum, with every night's work. This will offer no great difficulty.

In his original paper, Dr. COBLENTZ expresses the hope that a sensitivity 100 times as great as that which he used may be obtained, by using a more powerful telescope, a more sensitive radiometer and more favorable mounting of the galvanometer. This would make possible radiometric work having wonderful possibilities. But even if we content ourselves with the sensitivity used by Dr. COBLENTZ at Mt. Hamilton, the future of radiometry is very bright. It is certain that, by the use of screens, our knowledge of the energy distribution in stellar spectra can be vastly increased and this knowledge correlated with laboratory experience will tell us much that is now unknown about the conditions existing in the stars. The study of double stars and variable stars will yield rich results. The question of absorption in space can be attacked with freedom from some of the difficulties which beset the observation of this phenomenon by other methods. The results which are certain to be obtained would seem to warrant some observatory possessing a large reflector in devoting two nights a week to the subject for a year or more.

SUMMARY.

The available data show no relation between the spectral energy distribution and the absolute total energy of the star.

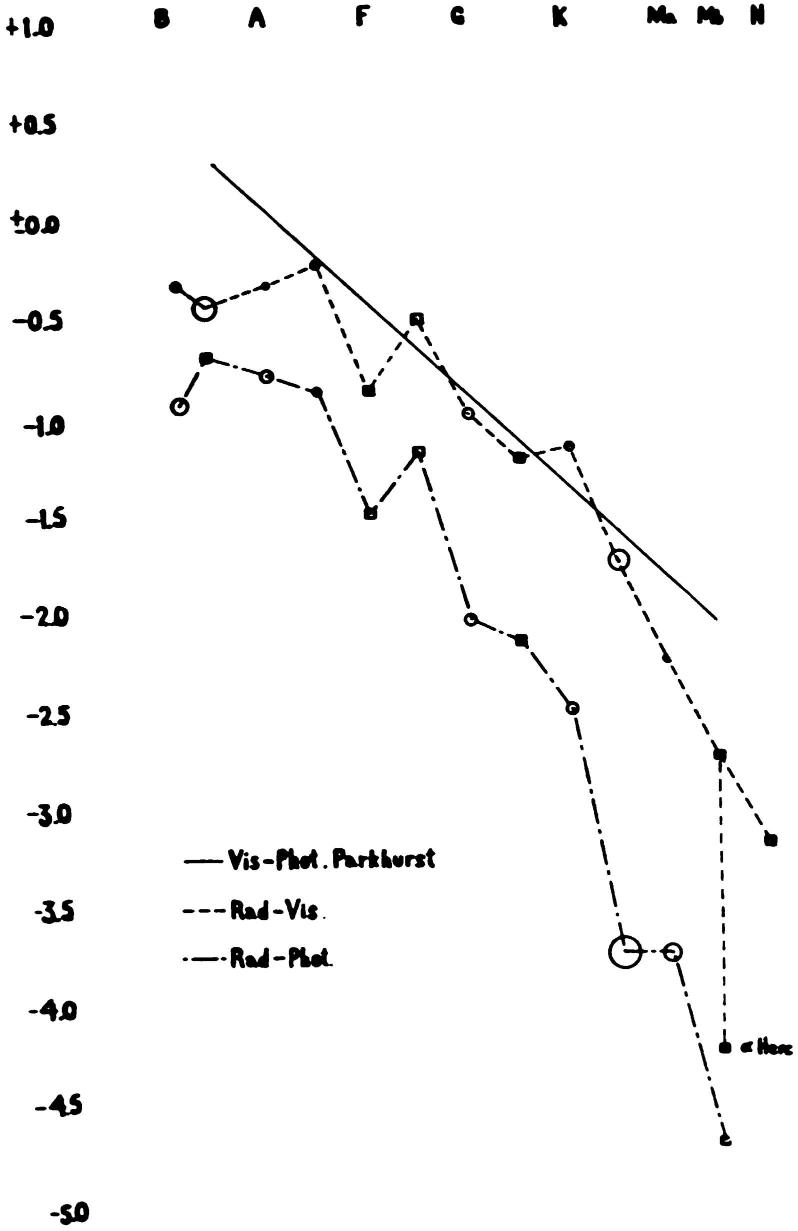
There is some evidence of absorption in space.

The fainter companion of a double star appears to have the same ratio of total energy to visibility as the primary, if any difference, the secondary is "redder."

The radiometric evidence points to a lower temperature for stars of class B than for stars of class A, but this is uncertain since the early type stars do not obey PLANCK's law. The stars of class G to Mb seem to have spectral energy curves roughly approximating PLANCK's law, and the temperature of such a star may be obtained from the percentage of its energy which is transmitted by a suitable screen.

The temperatures found for stars of classes G to Mb are thought to be correct within a few hundred degrees.

This paper is to quite an extent merely a more detailed statement of points brought out by Dr. COBLENTZ in his original paper.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THE EMISSIVITY OF STARS AT DIFFERENT TEMPERATURES.

By Paul W. Merrill.

On account of the remarkable and promising measures of the total radiation of stars, recently made by Coblentz,[1] it may be of interest to put in more accessible form a notion proposed by Nordmann and reported in the *Comptes Rendus* for March 13, 1913, and to apply it to the observed "emissivity" of stars of different colors.

Let M be the emissivity, i. e., the ratio of the heat radiated by an object to its brightness. Assume that the brightness is proportional to the intensity of the ray of wave-length 5400A. This is borne out by experiments in the laboratory, and by tests on stars. Using the Planck formula for spectral distribution of energy,—

$$E_\lambda = c_1\,\lambda^{-5}\,\left(e^{\frac{c_2}{\lambda T}} - 1\right)^{-1}$$

and the Stefan-Boltzmann law of total radiation,—

$$E = \sigma T^4$$

we have for a black body,—

$$M = A\,(e^{K/T} - 1)\,T^4$$

where T = absolute temperature in degrees Centigrade,—
K = 27000
A = a constant whose value is not needed here.

If B = brightness, and E = total radiation, we have for stars 1 and 2,—

$$M_1 = \frac{E_1}{B_1};\ M_2 = \frac{E_2}{B_2}$$

L, the relative emissivity, is defined by the following equation:—

$$L = \frac{M_2}{M_1} = \frac{B_1}{B_2} \times \frac{E_2}{E_1} = \frac{(e^{K/T_2} - 1)\,T_2^4}{(e^{K/T_1} - 1)\,T_1^4}$$

$$\log \frac{B_1}{B_2} = 0.400\,(\mathrm{Mag}_2 - \mathrm{Mag}_1)$$

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[1] *Publ. A. S. P.*, **26**, 169, 1914; *Lick Obsy. Bull.*, **8**, 104, 1915.

Next,—

$$\frac{M_2}{A} = (e^{K/T_2} - 1)\, T_2^4 = L\, (e^{K/T_1} - 1)\, T_1^4$$

This equation will enable T_2 to be found if L is known, and T_1 be known or assumed. Table I is to facilitate the numerical computation.

TABLE I.

$M = (e^{K/T} - 1)\, T^4 \times$ constant.

T	M	T	M
2000°	117.	7000°	0.92
2500	19.1	8000	1.16
3000	6.56	9000	1.25
3500	3.28	10000	1.39
4000	2.18	12000	1.76
4500	1.65	15000	2.56
5000	1.38	20000	4.57
6000	1.15	25000	7.60

As illustrated by Table I, the theory states that the emissivity reaches a minimum value for a temperature of 6900°, about that of the Sun. COBLENTZ finds, however, that the hotter stars, i. e., those of spectral classes A and B, have a lower emissivity than solar stars. This is probably due to the non-conformity of the energy curve with that of a black body. Hence we shall not attempt to determine the temperatures of stars "bluer" than the Sun by this method. Since M reaches a minimum for T = 6900°, a limiting value of T_2 can be found without assumption as to T_1 by putting in for it the value 6900°.

Let us take, for an example, *β Draconis* as star 1, and determine the temperature of other stars with respect to it. The following small table will be of assistance:—

TABLE II.

T depending on values of L relative to *β Draconis*.

	Assumed temperatures of *β Draconis*		
T	5000°	6000°	7000°
2000°	84.8	102.	127.
2500	13.84	16.61	20.75
3000	4.76	5.70	7.13
3500	2.38	2.85	3.56

	1.57	1.90	2.37
500	1.20	1.43	1.79
5000	1.00	1.20	1.50
6000	0.84	1.00	1.25
7000	0.67	0.80	1.00

β *Draconis* Class G; $\text{Mag}_1 = 2.99$; $E_1 = 0.44$
α *Boötis* Class K; $\text{Mag}_2 = 0.24$; $E_2 = 8.58$
$L = 1.50$
β *Pegasi* Class MB; $\text{Mag}_2 = 2.61$; $E_2 = 2.82$
$L = 4.5$
19 *Piscium* Class N; $\text{Mag}_2 = 5.30$; $E_2 = 0.46$
$L = 8.8$

Assumed T of	Resulting Temperature of		
β *Draconis*	α *Boötis*	β *Pegasi*	19 *Piscium*
5000°	4100°	3050°	2700°
6000	4400	3200	2800
7000	5000	3350	2900

The numbers in the last row represent upper limits.

For the double stars measured it is remarkable to find that in every case L is larger for the faint "blue" companion than for the primary. It is interesting to note that the bright-line star γ *Cassiopeiæ* gives a low value of L compared with other stars of class B. This may indicate that the photosphere (effective radiating layer) is nearer the outside than usual, so that, while the ultra-violet radiations are still strongly absorbed, visual rays are allowed to pass more freely than in the average star of class B.

Ann Arbor, Mich., March, 1915.

THE IMPORTANCE OF OBSERVING METEORS.[1]

By F. R. Moulton.

No other branch of practical astronomy offers so great an opportunity for interesting and scientifically important work, to one possessing only a meager or no instrumental equipment, as that of observing meteors. In fact, most of the work in this line can be done entirely without instruments, and those who are under obligations to employ powerful telescopes for the purposes for which they are designed cannot even undertake it. The purpose of this article is to point out the things (most of which are of course well known) which observations of the meteors may teach us. They will be mentioned in the order of simplicity of making the observations.

1. The simplest thing to do is to record the number of meteors which can be seen during a given interval of time. This is obviously done without any instrumental help, and in order to get enough data to be of any particular value an enormous amount of time is required. To make such observations of the greatest value, the date on which they are made and the precise part of the day should be recorded, and a part of the sky of definite size and location should be watched. Such observations can be expected to give the variation in the number of meteors visible at the different parts of the year and of the day, and in various parts of the sky. These are obviously questions of the first importance in determining their distribution in space. For example, astronomers wish to know whether all meteors are the remains of disintegrated comets, or whether most of them circulate around the Sun like infinitesimal planets, or whether many may not be wanderers in interstellar space and thick enough to cut off appreciably the light of distant stars. This last question is one of importance in connection with that of the extent of the

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[1] Reprinted from *Mon. Reg. Soc. Prac. Astron.*, March, 1915.

The general policy of the Publication Committee is not to reprint articles which have been published elsewhere and which are readily accessible to our readers. We make an exception in the present instance because we wish to emphasize the fact that, however many powerful telescopes may be in use, there is still a great deal of valuable practical astronomical work that can be done, and, indeed, *must* be done with "meager or no instrumental equipment." Publication Committee.

sidereal system, and is now a very live subject, as the readers of KAPTEYN's papers know.

In addition to simple counts of meteors, it is easy to record their color, their apparent speed, and their brightness as compared with the stars.

2. Everyone is familiar with the fact that many meteors belong to "streams," that is, they move in parallel paths across the orbit of the Earth. In order to establish a meteor stream, or to contribute to the proof of the existence of a meteor stream, the apparent paths of the meteors must be recorded. This can be done only on star maps[1] prepared in advance. There is abundant opportunity for the exercise of skill in making these observations. The degree of accuracy of the work can be checked by two or more observers working together, at least occasionally. Work of this kind has been industriously carried out by English observers, who have less favorable climatic conditions than prevail in most parts of the United States.

3. The height of meteors can be determined from simultaneous observations by two observers a few miles apart. Observations have shown that meteors usually become visible at a height of sixty to ninety miles above the Earth's surface. Hence the distance between the observers may be anywhere from five to fifteen miles. In order to be sure that both observers have seen the same meteor, the exact time and other circumstances of its appearance should be carefully recorded.

4. Now and then bright meteors leave luminous trains which are visible from a few seconds up to many minutes. *The motions of these trains should always be very carefully observed and their positions with respect to the stars recorded as accurately as possible from time to time as long as they are visible.* Such observations will give us information regarding the movements of the upper atmosphere at a height which can be reached in no other known way. Meteorologists are eager for any information in this line which can be obtained. It is clear that it is especially valuable when the meteor is observed by two observers a few miles apart so that its altitude can be determined with considerable certainty.

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[1] See *Publ. A. S. P.*, **28**, 101, 1915.

5. For some purposes it is important to know with what speed meteors move when they enter the Earth's atmosphere. If a meteor is observed by two persons a few miles apart the length of its path can be computed. Hence, in order to get its speed, it is necessary only to know how long was required for it to describe its path. This can be estimated with some approximation by experienced observers. A much more accurate way, which at the same time gives the position of the meteor accurately, is to photograph the sky with a camera following the stars and having in front of its objective a rotating screen which alternately admits and cuts off the light. The star images will be definite points and the meteor trail instead of being a continuous line will be a series of dashes corresponding to the times when the screen was edgewise to the camera objective. The photographs from the two places will locate the meteor, and, if the rate of rotation of the screen is known, its speed can be computed.

6. Finally, if in addition to the data of (5) the brightness of the meteor is determined, its mass can be computed. For, when a meteor strikes the atmosphere its energy of motion is largely changed to light, and the brightness of a meteor at a known distance and of a known duration furnishes the amount of radiant energy it emits. The brightness can be determined, of course, by comparing its trail with the star images, taking into account the length of the exposure. Now the energy of motion of the meteor, which is changed into a measured quantity of light energy, is proportional to the product of the mass and the square of the speed, which can be computed from the observations of (5). Hence the mass can be computed. Then, with the data of (1) it is possible to compute how fast the Earth is growing by the accretion of meteoric matter.

This will serve to show the great importance of observing meteors, and professional astronomers will welcome all additions to observers who follow these objects.

THE UNIVERSITY OF CHICAGO, CHICAGO, ILL.,
March 22, 1915.

PLANETARY PHENOMENA FOR JULY AND ANGUST, 1915.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter..	July 3,	9^{h} 54^{m} P.M.	Last Quarter...	Aug. 2,	1^{h} 27^{m} P.M.
New Moon....	" 12,	1 31 A.M.	New Moon....	" 10,	2 52 P.M.
First Quarter.	" 19,	1 9 P.M.	First Quarter..	" 17,	6 17 P.M.
Full Moon....	" 26,	4 11 A.M.	Full Moon.....	" 24,	1 40 P.M.

The second and last eclipse of the year is a central eclipse of the Sun, occurring on August 10th. Like the eclipse of February, it will not be visible in America, the path of the center being wholly in the Pacific Ocean from a point between Japan and the Philippines to a point in the southern hemisphere south of Mexico; also on account of the more than average distance of the Moon from the Earth and its small apparent size it will, like the eclipse of February, be annular and not total, consequently of small scientific interest.

The Earth will be in aphelion on July 5th.

Mercury will be a morning star during the greater part of July and August. It passed inferior conjunction on June 26th and will come to superior conjunction on August 14th. Greatest west elongation will be reached on July 18th; it is then 20° 23′ west of the Sun and will rise 1^{h} 20^{m} before the Sun, and the interval will remain more than an hour until after August 1st. It will therefore be in fair position in the morning twilight for about three weeks. It will be in conjunction with *Venus* twice, the first time on July 10th, when both are too near the Sun for easy observation of the fainter planet, the second on August 4th, in the early morning. *Mercury* will then be 0° 18′, a little more than half the Moon's apparent diameter, north of *Venus*. At the same hour it will also be in conjunction with *Neptune*, 1° 21′ north of the latter. On July 22nd it passes 1° south of *Saturn*, both planets being below our horizon at the time of nearest approach, but they will not be far apart on the mornings before and after.

Venus is drawing near superior conjunction with the Sun, but remains a morning star. On July 1st it rises about $1^h 20^m$ before sunrise, but the interval diminishes to less than twenty minutes by the end of August. It will then be nearly at its maximum distance from the Earth, and consequently at nearly its minimum brightness, but it will still be bright enuf to be seen without a telescope until nearly the end of August. It will be in conjunction with *Saturn* on the morning of July 17th, passing 0° 38′ north; also with *Neptune* on the morning of August 4th, passing 1° 3′ north. The conjunctions with *Mercury* have already been mentioned.

Mars rises at about 2 A. M. on July 1st and at about 12:30 A. M. at the end of August. It moves about 45° eastward and 5° northward thru *Taurus* into *Gemini*. On July 1st it is about 5° south of the *Pleiades*. Just after the middle of the month it is rather near the first magnitude red star *Aldebaran*, passing about 5° north of the star on July 19th. By the end of August it will be about 10° south and west of *Castor* and *Pollux*, α and β *Geminorum*. During the two months its distance from the Earth will diminish about twenty-five millions of miles and its brightness will increase about twenty per cent. At the end of August it will be about twice as bright as it was when at its faintest in the autumn of 1914. That is, it will be about as bright as a normal first magnitude star.

Jupiter is nearing opposition with the Sun, rising about 11:30 P. M. on July 1st, and shortly after 7 P. M. on August 31st. It is in the constellation *Pisces*, a short distance west and south of the vernal equinox. Up to July 19th it moves about the Moon's apparent diameter eastward and northward. It then begins its westward or retrograde motion, reaching on August 6th a position about 10′ south of its place on July 1st. During the rest of the month it moves about 2° in the same direction, reaching a point about 20′ south of its position in early June.

Saturn passed conjunction with the Sun on June 28th and became a morning star. Its distance from the Sun increases rapidly, so that it reaches a position fit for naked-eye observation in the morning twilight by the middle of July. By August 1st it rises before 3 A. M., and at the end of that month at about 1 A. M. It is moving eastward, about 8° in the constellation *Gemini*, about 10° west and south of *Castor* and *Pollux*. Its conjunction with *Venus* on July 17th and with *Mercury* on July 22nd have been mentioned. By the end of August it is about 6° east of *Mars*.

Uranus is in fair position for observation as it comes to opposition with the Sun on August 6th. It is in the constellation *Capricorn* and moves about 2° westward and southward during the two months. No bright star is near, but in early July it is about 2° west of the fourth-magnitude star *ι Capricorni*, and the subsequent motion of the planet carries it away from the star. By the end of August it will be only a few minutes east and south of another fourth-magnitude star, *θ Capricorni*. It will be occulted by the Moon on the night of July 26-27th, visible in the United States, and again on August 23rd, not visible in this country.

Neptune is in conjunction with the Sun on July 23rd. Its conjunctions with *Mercury* and *Venus* on August 4th have been mentioned.

NOTE.

The next number of these Publications will be issued in the latter part of August, instead of on August 10th, to permit the inclusion of an account of the proceedings of the August meeting of the American Astronomical Society.

Publication Committee.

NOTES FROM PACIFIC COAST OBSERVATORIES.

AN ERROR IN RADIAL VELOCITY OBSERVATIONS ARISING FROM NON-UNIFORM SLIT ILLUMINATION.

Some observations of the planet *Venus* secured with the 3-prism Mills spectrograph attached to the 36-inch refractor give strong evidence that an imperfect or unsymmetrical illumination of the slit, by the light source, may introduce error in the resulting radial velocities. These observations were secured when the terminator of *Venus* was nearly a straight line. The slit was made parallel to the terminator, and was placed either just inside the terminator or just inside the section of the limb immediately opposite the center of the terminator, as judged from the image of the planet on the slit plates. Ten observations of the radial velocity of the planet were obtained with the slit just inside the terminator and ten with the slit just inside the limb, with the prism box and camera directed to the west. The spectrograph was then rotated 180° about the axis of the telescope until the prism box and camera pointed east, with the slit again parallel to the terminator line. In this position of the spectrograph, nine observations were made with the slit just inside the terminator, and nine with the slit just inside the limb.

In the first position of the spectrograph, that is, with camera west, the ten observed radial velocities of the limb minus the ten of the terminator had an average value of $-0.51 \pm 0.08^{\mathrm{km}}$ per second.

In the second position of the instrument, that is with camera east, the nine observed radial velocities of the limb minus the nine of the terminator had the average value of $+0.75 \pm 0.12^{\mathrm{km}}$ per second.

The difference of the two mean results, 1.26^{km}, is, in my opinion, attributable to the fact that the slit was not uniformly illuminated by the planet's image. Guiding was based upon a nage of the planet, as formed by the 36-inch objective a correcting lens one meter in front of the slit. This correcting lens is figured for the blue and violet rays. Guiding was chiefly by virtue of the yellow rays. The yellow image was undoubtedly larger than the blue-violet image to which the radial velocity measures were intended to relate. The slit was probably not so far inside the boundary lines of the blue-violet image as the visual guiding image indicated. It is probable that the blue-violet image was so much smaller than the guiding image that the former did not always extend entirely across the slit. The systematic errors are in the direction explainable by the assumption that in half the observations the image was stronger on the east edge of the slit than on the west edge, and *vice versa* for the other half of the observations. The slit width used was 0.0014 inch (0.036^{mm}).

Errors of the same nature probably enter into radial velocity results for stars, provided the observer in guiding upon the stellar image has a systematic tendency which leads him to keep the center of the image nearer one edge of the slit than the other, or in case the image is not symmetrical, owing to faulty collimation, atmospheric refraction, etc., or if the adjustment of the telescope is such that with the progress of time the stellar image drifts systematically off the slit in one direction.

A high degree of accuracy calls for care in the symmetry of the stellar image and symmetry of the image with reference to the central line of the slit of the spectrograph.

It is possible that atmospheric dispersion distorted the image of *Venus* sufficiently to introduce guiding errors in the radial velocities of the planet described above.

W. W. CAMPBELL.

NOTE ON COMET *a* 1915 (MELLISH).

Since the last issue of these *Publications*, a third orbit of this comet has been derived from observations of February 13th, February 27th, and March 19th, all of which were made by Dr. AITKEN.

This orbit shows a slight change from that mentioned by Dr. AITKEN in the April number of this magazine. It brings the time of nearest approach to the Sun forward to July 17th.

On that date the comet will be just a little more than unit distance (the mean distance of the Earth from the Sun) from the Sun. Its motion is in a plane inclined 54° to that of the ecliptic. The nearest approach to the Earth will be June 5th, when it will be distant from us a little less than forty million miles. On that date it will attain its maximum brilliancy, 205 times that at discovery. It will then probably be of about the second magnitude. At that time it will be 68° south of the equator, so that it cannot be seen from this latitude.

The orbit of this comet is somewhat similar to that of the second comet of the year 1748. Computations show, however, that the two comets are probably not identical.

R. T. CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT,
May 15, 1915.

COMPANIONS TO MELLISH'S COMET.

A telegram from the Harvard College Observatory was received on May 13th, announcing the discovery by Professor BARNARD, of the Yerkes Observatory, of two companions to Mellish's Comet, on May 12th. One of these was described as "conspicuous, 28″ from the nucleus in position-angle 285°," the other as "faint, intermediate in distance in the same line."

Unfavorable weather conditions had prevented observations of this comet here for the two weeks preceding May 12th, and did not permit a verification of Professor BARNARD's discovery until the night of May 14th. The 12-inch refractor on that date showed the brighter companion at the first glance, but haze and, later, clouds, made it impossible to see the fainter one. My measure of the bright companion is:—

May 14, 1915, $13^h 56^m$; distance, 35″.2 in 285°.2.

According to this measure the companion is slowly receding from the nucleus. Stormy weather has made further measures impossible.

R. G. AITKEN.

May 19, 1915.

SEVEN SPECTROSCOPIC BINARIES.

	Mag.	Spec.	R.A. 1910	Dec. 1910	Range in Velocity, km
Lalande 2682	7.8	K1	$1^h 24^m.1$	+21° 16′	—17 to +47
Boss 1082	5.3	G4	4 32 .8	+52 54	0 to —66
A. G. C. 3881	8.0	A2p	9 24 .6	+33 42	Composite
Boss 2951	6.4	A1	11 2 .8	+23 49	—13 to +32
Boss 3108	5.8	K5	11 46 .4	—4 50	—2 to +26
Boss 3284	6.7	A3p	12 30 .6	+18 52	Composite
Boss 5173	5.5	A0p	20 6 .8	+26 38	Composite

NOTES.

A. G. C. 3881.—Two plates show double lines. A photograph taken on January 5th gives for the velocities of the two components —41 and +81$^{\text{km}}$. Boss 3284. The third spectrogram showed the presence of two spectra. The velocities given by this plate are —70 and +57$^{\text{km}}$. Boss 5173.—The hydrogen lines in this star show great variations in width and intensity, due probably to the presence of two spectra. A relative displacement of about 150$^{\text{km}}$ between the components is indicated by the first plate.

All of the photographs were taken with low dispersion.

WALTER S. ADAMS.

THREE STARS WITH GREAT RADIAL VELOCITIES.

The following stars have been found to have exceptionally high radial velocities:—

	Mag.	Spec.	R.A. 1910	Dec. 1910	μ	v	No. Plates
W. B. 3^h 617	7.2	F5	$3^h 35^m.8$	—3° 31′	0″.78	+114$^{\text{km}}$	3
W. B. 17^h 514	8.6	F1	17 30 .4	+6 4	0 .58	—148	4
O. Arg. 20,452	8.1	G0p	20 18 .3	—21 38	1 .21	—179	4

WALTER S. ADAMS.

THE SPECTRUM OF T TAURI.

A recent photograph of the spectrum of the well-known irregular variable T *Tauri* shows some interesting peculiarities. The spectrum is compound and consists of a considerable number of well-defined bright lines superposed on a dark line spectrum of about type F5. The fact that bright lines cover $H\beta$, $H\gamma$, and H and K makes it difficult to classify the absorption spectrum closely. Measures of the photograph give the following wave-lengths for the bright lines, corrected for radial velocity:—

3889 *H*	[illegible]	4511
3933 *Ca*	4116	457[illegible]
3968 *Ca*	4233	4613
4070	4340 *H*	4861 *H*
4102 *H*	4471 *He*	4922 *He*

The small scale of the negative (2.1mm from K to *Hβ*) prevents more accurate determinations. In the absorption spectrum numerous dark lines are present, including λ 4227, 4308, and several of the stronger iron lines.

The bright line spectrum of this star is very closely analogous to that of the Wolf-Rayet star B.D. − 30° 3639, both as regards the lines present and their character. It suggests, therefore, the presence of an extensive atmosphere such as is known to exist in the case of the Wolf-Rayet star. The photograph, unfortunately, was taken under very poor observing conditions, so that the image of the star filled essentially the whole of the aperture in the spectrograph window. As it is, however, the bright lines appear to project in undiminished intensity beyond the point at which the continuous spectrum begins to fade away. The presence of an extensive atmosphere is made almost certain by direct photographs which show a nebulous appendage to the star projecting to a distance of about 4" from the center of the image. This nebulosity, however, is not symmetrical with reference to the star.

The radial velocity as determined from three of the bright hydrogen lines and bright H and K is −8 km. We hope shortly to obtain spectra of the star with higher dispersion, which will be more suitable for detailed study.

W. S. ADAMS.
F. G. PEASE.

THE RADIAL VELOCITY OF THE NEBULA N.G.C. 1068

A photograph of the bright line nebula N.G.C. 1068 was obtained recently with the small-slit spectrograph at the primary focus of the 60-inch reflector. Measures by Mr. ADAMS and Miss BURWELL of the two nebular lines λ 4959 and λ 5007 give for its radial velocity reduced to the Sun a value of $+765^{\text{km}}$.

SLIPHER has given a velocity of $+1100^{\text{km}}$ for this nebula.

FRANCIS G. PEASE.

RADIAL VELOCITY OF THE ANDROMEDA NEBULA.

An excellent spectrogram of the *Andromeda* nebula was obtained on the nights of November 12th, 13th, 14th, 15th and 16th, 1914, with the small-slit spectrograph at the primary focus of the 60-inch reflector. The total exposure time was thirty-four hours on a Seed 27 plate, with a slit width of 0.025^{mm}. The spectrum is G type, the more prominent lines extending over a minute of arc either side of the nucleus (slit E-W). The mean measured velocity given by nine lines is -329^{km} reduced to the Sun. The plate was measured by Mr. ADAMS. Other values, mentioned by SLIPHER in his paper on spectrographic observations of nebulæ in the report of the seventeenth meeting of the American Astronomical Society are:—

WOLF	-350^{km}	per sec.
WRIGHT	-304	" "
SLIPHER	-300	" "

There seems to be no evidence indicating the presence either of bright lines or of a rotational displacement.

FRANCIS G. PEASE.

FOUR NEW VARIABLE STARS IN THE HERCULES CLUSTER.

In the globular cluster Messier 13 the following stars have been found to vary in light:—

No. of Star			
Ludendorff.	Scheiner.	No. of Plates.	Observed Range.
135	89	6	$15^{\text{m}}.0$ - $16^{\text{m}}.0$
322	...	5	15 .4 - 16 .0
806	628	6	14 .7 - 15 .8
872	667	6	14 .2 - 14 .8

The third star of this list is the northern component of a close double. The periods of all are probably short. Of the thousand brightest stars in the cluster, only two others are known to be variables—Nos. 306 and 816 of LUDENDORFF'S catalog.

HARLOW SHAPLEY.

NOTE ON THE PERIODS OF CLOSE BINARIES.

In reviewing two recent statistical studies of spectroscopic binaries in the April number of the *Publications,* Mr. PADDOCK finds in the investigation of orbital eccentricities by JORDAN[1] a possible verification of WICKSELL'S[2] conclusion that two orders of period exist for the various spectral classes. It is not necessary, however, to depend on spectroscopic orbits alone for a further examination of this question, for the only data necessary to test the hypothesis are the periods and spectral types of close double stars. We may combine the results for both eclipsing and spectroscopic binaries, and the material, while still homogeneous, is more than doubled. The most recent results are included in the following table:—

LOGARITHM OF PERIOD AND SPECTRAL TYPE.

Spectrum	−0.8 to −0.4	−0.4 to 0.0	0.0 to +0.4	+0.4 to +0.8	+0.8 to +1.2	+1.2 to +1.6	+1.6 to +2.0	+2.0 to +2.4	+2.4 to +2.8	+2.8 to +3.2	+3.2 to + 3.6	+ 3.6 to + 4.0	Total No. of Binaries
B	..	..	9	16	10	6	..	6	..	..	..	..	47
A	..	9	26	40	14	9	3	2	..	1	1	..	105
F-G-K	2	3	3	10	5	4	4	5	5	3	1	2	47
Total	2	12	38	66	29	19	7	13	5	4	2	2	199

It is seen at once that the double grouping of periods has disappeared (except for six stars of spectrum B). We should remember, however, that rather complicated conditions of selection have influenced the present lists of both spectroscopic and eclipsing binaries, so that any statistical conclusion must be to some extent conditional and temporary. The frequency curves and a fuller discussion of the subject will appear in the current number of the *Astrophysical Journal.*

HARLOW SHAPLEY.

HONORS FOR PROFESSOR LEUSCHNER AND PROFESSOR STEBBINS.

The National Academy of Sciences at its April meeting in Washington conferred the Watson Gold Medal upon Professor A. O. LEUSCHNER, Director of the Students' Observatory, University of California, in recognition of the great value of his contributions to the theory and practice of orbit determination, special reference to his development of the "Short [ethod."

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[1] *Publ. All. Obs.,* **3**, 158.

[2] *Arkiv för Matematik, Astronomi och Fysik,* **10**, No. 6, 1914.

The National Academy at the same meeting bestowed the Henry Draper Gold Medal upon Dr. JOEL STEBBINS, Professor of Astronomy in the University of Illinois, in appreciation of his sustained investigations which led to the perfecting of the selenium photometer. Professor STEBBINS had received, in 1914, the Rumford Medal of the American Academy of Arts and Sciences, in recognition of the same services.

The Lick Observatory is pleased to recall that Mr. LEUSCHNER was a special student in the Lick Observatory during the years 1888-1890, and that Mr. STEBBINS was a Fellow in the Lick Observatory during the years 1902-04.

ASTRONOMY AT THE SUMMER SESSION, UNIVERSITY OF CALIFORNIA.

An unusual opportunity is this year afforded to students in other universities who wish to gain a knowledge of the theory and practice of orbit computation as developed at the Students' Observatory, Berkeley. Professor LEUSCHNER announces that he will give a course on Orbit Theory and conduct a seminar on the same subject in the Summer Session of the University, opening on June 21, 1915. The two courses are open to students "familiar with the differential and integral calculus and with the fundamental principles of general and practical astronomy."

Dr. NICHOLSON will conduct two courses in general astronomy during the Summer Session, one for students without previous knowledge of the subject, the other a more advanced course.

PERSONAL NOTES.

Miss MARGARET HARWOOD, holder of the Nantucket Maria Mitchell Association Fellowship, who will be a graduate student in the Berkeley Astronomical Department during the next academic year, will spend the summer vacation months in residence at the Lick Observatory.

Mr. W. K. GREEN has been reappointed University Fellow in the Lick Observatory for the next academic year.

Mr. R. F. SANFORD, Assistant Astronomer on the D. O. Mills Foundation, with residence during the past four years in Chile, has resigned and is returning to the United States in June. Prior to his connection with the D. O. Mills Expedition, Mr. SANFORD was an assistant in the Carnegie Institution Observatory at San Luis, Argentina, during three years. During the two years preceding, Mr. SANFORD was a Carnegie Institution assistant in the Lick Observatory.

Assistant Astronomer R. E. WILSON, in charge of the D. O. Mills Expedition to the southern hemisphere during the past two years, has been promoted to the position of Acting Astronomer in charge of the Expedition for the academic years 1915-17.

Mr. A. A. SCOTT, assistant, in service with the D. O. Mills Expedition during the past year and one-half, has been reappointed for the next academic year.

Mr SETH B. NICHOLSON was awarded the degree of Doctor of Philosophy at the commencement exercises of the University of California, May 12, 1915. Dr. NICHOLSON's thesis was on the subject, "The Discovery, Observations and Orbit of the Ninth Satellite of *Jupiter*." This thesis is being published in the *Lick Observatory Bulletin*.

In this connection it is a pleasure to call attention to the very high praise[1] accorded to Dr. NICHOLSON's announcement of the discovery of this satellite, in the October, 1914, number of these *Publications*, by the eminent English astronomer who contributes the notes "From an Oxford Note Book" to *The Observatory*.

Another Ph.D. degree awarded at this commencement will be of interest to astronomers. Mr. F. E. PERNOT made astronomy (celestial mechanics) his principal minor, his major subject being physics.

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[1] See *The Observatory*, April, 1915, p. 193.

STRACTS FROM ASTRONOMICAL PUBLICATIONS.

Review: The Spectroscopy of the Extreme Ultra-Violet.[1]

This interesting book is a history of the extension of our knowledge of the solar spectrum and especially of the spectra of the chemical elements into those regions of short wave-lengths known as the ultra-violet and extreme ultra-violet.

The human eye is able to follow the solar spectrum into the violet to the vicinity of the radiations whose wave-lengths are designated as 3900 Angstroms. In 1842 Becquerel photographed the solar spectrum 500 units farther into the violet, to 3400 A. A little later Stokes substituted quartz for glass in the lenses and prisms of the spectroscope, and a fluorescent screen for the Daguerreotype plate, and by these means he was able to follow the bright lines in a laboratory spectrum into the ultra-violet possibly to 1850 A. The solar spectrum, for an observer on the Earth, seems to terminate at about 2900 A. Cornu attributed this limitation to the absorption of our atmosphere, and there remains no doubt that this explanation is the correct one. Miethe and Lehmann, who made a special investigation of the subject, concluded that the limit of the solar spectrum in the ultra-violet is essentially independent of the observer's altitude above sea-level. They observed at various altitudes, from fifty meters up to 4,560 meters. Their results for the extreme altitudes were—

Berlin, 50 meters; limit of solar spectrum, 2912.6A
Mt. Rosa, 4560 meters; limit of solar spectrum, 2912.1A

Wigand, who photographed thru a screen (in front of the slit of his spectrograph) which was transparent to radiations in the region of 2900 A and opaque to other radiations, reported the limit of the solar spectrum to be at 2897 A. Why the solar spectrum is cut off so abruptly at this point is not yet fully determined; some investigators ascribe it to absorption by oxygen in the air, and others to absorption by ozone.

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[1] By Theodore Lyman, Assistant Professor of Physics in Harvard University. Octavo, pp. 135. 5 shillings net. Longmans, Green & Co., London, 1914.

The arc and spark spectra of the chemical elements are brilliant in ultra-violet, and they have been observed satisfactorily in the laboratories, by means of ordinary concave-grating spectrographs, to the vicinity of 2000 A. Spectrographs containing glass prisms or lenses are useless in the ultra-violet, as they are opaque to the radiations. As examples: the thin cover glass of a microscopic slide, placed over the slit of a spectrograph, will limit the spectrum at about 2850 A; and SCHOTT's uviol cover glass will place the limit near 2480 A Quartz prisms and lenses permit a further extension into the ultra-violet, but fluorite is much more transparent than quartz in this region. However, the atmosphere surrounding the spectrograph becomes prohibitively absorptive at about 1850 A. SCHUMANN determined that radiations at 1940 A may be photographed thru fourteen meters of air and a fluorite spectrograph, whereas radiations at 1750 A may not be photographed thru one centimeter of air. This he attributed to an oxygen absorption band extending from 1900 A to at least 1300 A. He found, further, that in this region the gelatine on the ordinary photographic plates prevented the radiations falling upon the plates from passing on to the silver bromide grains immersed in the gelatine film.

With remarkable skill and perseverance, in the face of enormous difficulties, VICTOR SCHUMANN, of Leipzig, determined the conditions under which laboratory spectra of gases and metals could be studied in the region 1850 A to 1230 A, and he applied the methods with great success to the spectra of the elements, especially of hydrogen. He used fluorite for the optical parts of the spectrograph; he placed the entire spectrograph in an air-tight case and exhausted the air to a pressure of 0.5 millimeter; he used specially-prepared dry plates containing a minimum of gelatine, and differing in other respects from ordinary plates; and the apparatus was immersed in a water bath to maintain it at constant temperature. The mechanical features of the apparatus were remarkable for their refinement.

Professor LYMAN's researches of the past decade have concerned a re-survey of the SCHUMANN region of laboratory spectra and an extension of the study to a region of still shorter wave-lengths. LYMAN's tables of wave-lengths extend to 1030 A, and recently he has succeeded in photographing as far as 905 A. He uses a concave Rowland speculum grating, radius of curvative 97 centimeters, ruled with nearly 600 lines to the millimeter. SCHUMANN's practices of working in vacuo and with special dry plates are of course followed. SCHUMANN's prismatic spectrum had the advantage of greater brilliancy, but LYMAN's grating spectra had the very important advantages of doing away with lenses, of having a long stretch of spectrum in accurate focus at one time, and of enabling the wave-lengths of spectrum lines to be determined very accurately. The positions of the lines were determined by the usual method of overlapping first- and second-order spectra, and likewise thru the ingenious device of two slits, separated by an interval of several centimeters, as light sources for two corresponding spectra on the same photographic plate.

The volume contains observational data of many kinds:

1. Tables of wave-lengths of bright lines in the spectra of hydrogen, nitrogen, carbon monoxide, argon, aluminum, calcium, strontium, barium, magnesium, mercury, silver, gold, cadnium, copper, tin, and zinc; principally by LYMAN, but in part by HANDKE and WOLFF.

2. On the absorption of ultra-violet light by solids, such as glass, quartz, fluorite and rock salt.

3. On the absorption of ultra-violet light by gases, such as atmospheric air, nitrogen, oxygen, ozone, carbon dioxide, carbon monoxide, helium, argon, hydrogen, and water vapor.

It is established that oxygen in the atmosphere is the chief obstacle to the passage of ultra-violet light. The part played by ozone is left in considerable doubt.

RITZ had predicted that lines in the "diffuse series" of the hydrogen spectrum should be found at 1215.6 A and 1025.7 A. LYMAN reports the presence of faint diffuse hydrogen lines at these points which are intensified by disruptive discharge thru the light source, whereas the other hydrogen lines in the neighborhood are weakened and blurred by this process.

Investigations on the extreme ultra-violet spectra of the elements, recently conducted by WOLFF, have found four zinc lines, five cadmium lines, and two mercury lines precisely, we may say, where PASCHEN has predicted them.

LYMAN's recent extension of the recorded spectrum to 905 A has been obtained chiefly by the use of a condenser and a spark gap in the circuit with the discharge tube which acts as the light source.

The bibliography of the "Spectroscopy of the Extreme Ultra-Violet" is listed extensively and very usefully in appendices. The volume closes with notes on the preparation of dry plates for photography in the SCHUMANN-LYMAN region of spectrum, and on the development of the plates.

Professor LYMAN's book can be consulted with advantage by all who are working with extreme ultra-violet radiations.

W. W. CAMPBELL.

GIANT AND DWARF STARS AND THE ORDER OF STELLAR EVOLUTION.

In 1905 and in 1910, HERTZSPRUNG[1] pointed out the existence of two orders of luminosity among the stars of the later spectral classes and distinguished the two kinds of bodies by the names giant and dwarf, with the idea that their difference of physical constitution is at least that of size. Since then our knowledge has increased, especially as to the visual, spectroscopic, and eclipsing binaries from which many of the physical properties of stars and stellar systems can be derived. RUSSELL has collected and discussed all available data and has not only supported the hypothesis of two kinds of stars, but has formulated a hypothesis of the order of stellar development to account for the giants and dwarfs. He first announced his results in an address to the Royal Astronomical Society in London, June, 1913,[2] and more fully explained them in an address to Section A of the American Association for the Advancement of Science at Atlanta, December, 1913.[3] About this time EDDINGTON[4] expressed the opinion that the prevailing hypothesis of the order of development from type B to type M was quite w ported by the relation of increasing periods in binary s ns and of increasing average peculiar motion of stars to the order B to M. Russell[5] responded to this opinion with a statement of objections to the present order B to M. These objections are briefly as follows:—

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[1] *Zeitschrift für Wissenschaftliche Photographie*, **3**, 442, 1905; *Astron. Nach.*, **185**, 90, 1910.

[2] *The Observatory*, **36**, 324, 1913.

[3] *Nature*, **93**, 227, 252, 281, 1914; *Popular Astronomy*, **22**, 275, 331, 1914.

[4] *The Observatory*, **36**, 470, 1913.

1. It is generally supposed that the stellar surface temperature and luminosity decrease together from class B to class M. But it is found that certain stars of all classes are of similar high luminosity.

2. It is generally accepted that class B stars have the highest temperatures, so that many intermediate stages of increasing temperature between diffused primordial matter and class B stars are to be expected. But there are too few in the sequence O, B, . . M.

3. The densities of class B stars are higher than expected for earliest stages, in fact higher than that of the Sun expanded only four-fold. In cooling from type B to type M they could not decrease in density, or expand, to the state of certain later type stars of extremely low density.

4. Class B stars are more massive than other classes; but it is not probable that mass diminishes with the transition from type B to type M.

5. The observed increase of period of spectroscopic binaries with advancing type is strong evidence against the order B to M, since in the theory of tidal evolution, there is a limit to the separation and the period. Long periods cannot evolve from short periods. Short-period binaries formed in early stages would remain relatively short; but such are absent in classes K and M.

6. The increase of average peculiar motion of the several spectral classes is unexplainable by the order B to M; but it is well explained by the hypothesis that velocity is greater in proportion as mass is less.

Russell has drawn his data from four groups of stars: first, 300 stars whose parallaxes have been more or less accurately determined; second, 150 members of the moving-clusters in *Taurus, Ursa Major, Cygnus, Scorpius,* whose parallaxes are known; third, 550 visual binaries whose hypothetical parallaxes and absolute magnitudes are derived by the statistical method; and 90 eclipsing variables for which Russell and Shapley have derived densities and hypothetical luminosities. Plots of the luminosities against the spectral sequence B, A, F, G, K, M, for each of the four groups of stars show similar results: namely, that the early class stars are the brightest; that the later class stars are both bright and faint, while class M entirely lacks stars of intermediate brightness of the order of that of the Sun; and finally that the range of luminosity increases with advancing type to the extent of a million-fold. The data of visual and spectroscopic binaries show a range of mass of fifty-fold, of mean mass only thirty-fold, and of density a great range. From the data pertaining to eclipsing variables it is evident that surface brightness diminishes with advancing spectral type, and that density has a tendency to increase among the less luminous stars, while among the most luminous stars density diminishes enormously —to one-millionth that of the Sun. The range is more than a million-fold.

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[5] *The Observatory,* **37**, 171, 1914.

Luminosity is affected by at least the three factors of mass, surface brightness, and density. The facts presented above allow the following inferences: The observed range of mass is too small to account for the great range of luminosity; if surface brightness is less for the later than for the early type stars, that factor cannot cause the great luminosity of some of the later type stars; since great and sufficient range of density is observed, density may well be the factor producing the great range of luminosity.

Two points, Russell thinks, may now be granted at least provisionally; namely, that these results or inferences represent stars in general and that in accordance with the Lane-Ritter law for gaseous bodies the stars under the action of gravitation condense and increase in density continuously, rise in temperature to a maximum and then gradually cool. Upon these points Russell bases the following hypothesis to account for the two orders of luminosity, using the terms giant and dwarf for the stars of great and of small luminosity, respectively:—

The spectral class M represents the earliest as well as the latest type of spectrum; when earliest, the star is of huge proportions with extremely low density and just beginning to rise in temperature, but when latest the star has reached its last stage of temperature and luminosity and nearly its greatest density. The classes K, G, F, A, represent intermediate stages both of rising and falling temperature. The giants and dwarfs are more and more nearly of the same order of luminosity until in class B they are undifferentiated. Class B represents the last type of spectrum and the highest stage of temperature and that of critical density at which a contracting body begins to diminish its heating and radiating power. The order of transition will then be M, K, G, F, A, B, A, F, G, K, M.

In support and explanation of the hypothesis he mentions the following points: The critical density corresponding to the maximum temperature was estimated by Lord KELVIN to be about one-tenth the density of water. Eclipsing binaries of classes B and A are found to have an average density about one-sixth that of water, a very close approach to the estimated value. The similar degree of luminosity among the giants of all classes may be due to the counteractive effects of increase of density and of surface brightness. The apparent scarcity of intermediate stages of increasing temperature between diffused primordial matter and class B stars in the present sequence of types is obviated by the proposed sequence and it is argued that it is more probable that the giant stars represent the early stages than that these stages have ceased to exist. The proposed order accounts for the relatively high density of class B stars and obviates the anomaly of class B stars becoming giants of type M. Presumably only the greater masses may attain the highest temperatures. This is substantiated by the well-established facts that class B stars are the most massive and have the highest temperatures. The smaller masses may not attain the highest temperature nor pass thru the entire sequence of spectral types. Many stars may have their turning points at K or G or F. The greater numbers in successive classes from B to M would probably cause a diminishing value of average mass and account for the fact that class

B stars are the most massive. The observed distribution of spectroscopic binaries and their periods may be explained thus: The formation of binaries will occur more frequently during the middle stages of condensation than in the earliest stages, so that binaries will be more numerous, and younger, and of shorter period, among stars in the middle stages of transition. Class B stars actually show the greater number of binaries and the shorter periods. The explanation of the increase of mean peculiar velocity of the classes from B to M upon the hypothesis that velocity is greater in proportion as mass is less, in connection with the proposed order of spectral transition, is substantiated by the observed diminishing increment of the velocity from class to class; in other words, the average of the mean peculiar velocities of the giants and dwarfs in those classes in which they are separated is very nearly of the same value.

The new hypothesis takes into account quite satisfactorily many hitherto unexplained points. But one very important point is untouched. Two incontrovertible facts are before us which must be taken into account in an acceptable hypothesis of stellar evolution. First, nebulosity is found associated only with spectral types B and O. Second, spectral type M, whether pertaining to the giant or dwarf character of star, is not known to be connected with nebulosity. The new hypothesis has searched for early stages between primordial matter, presumably nebulosity, and class B stars, but it has not found stages previous to its own earliest forms, the giants of class M. If the M type giants transform to the B type, a cause must be discovered either for the production of nebulosity about them in the latter stage, or for their introduction into nebulosity. Since the giants share, in part at least, the peculiar velocity of the later class stars, the loss of this motion would have to be accounted for upon their attainment of spectral type B. A crucial point is, What part does nebulosity play in the physical transition of stars, and it may be asked, whether nebulosity may or may not produce particular spectral effects or types, irrespective of the effects proceeding out of the physical transition in accordance with the LANE-RITTER law.

May, 1915. G. F. PADDOCK.

GENERAL NOTES.

Simplified Spelling.—In the April, 1915, number of *The Observatory,* the editor of the notes "From an Oxford Notebook" quotes a sentence from the *Publications A. S. P.,* and comments,—"More than one correspondent has drawn my attention to the modern American spelling and asked for a protest; but in questions of taste, such as the spelling of 'thru,' there is much to be said for letting every one choose for himself." For this mild approval of the very few and conservative reformed spellings adopted in these *Publications* the editors are duly grateful. A mis-print, commented on by the Oxford astronomer, warns us, however, that it may be well to state just what simplifications are intentional, lest we be credited with greater radicalism than is our due.

To express our approval of the movement to effect some degree of reform in our spelling we have decided to adopt the spellings **tho, altho, thru, thru-out thoro, enuf, program, catalog,** and, in general, the simpler of any two "authorized" forms. When spellings like "unforseen" are encountered, credit, or the lack of it, should be given to the proofreader.

The eighteenth meeting of the American Astronomical Society will be held in joint session with the meeting of the American Association for the Advancement of Science, at San Francisco and Berkeley, California, August 2-7, 1915. The program arranged by the local committee is as follows:—

Monday, August 2nd—

The first general session of the American Association for the Advancement of Science will be held in San Francisco at 10 A. M., and will include the addresses of welcome and response, and the President's address. A reception to the members of the A. A. A. S. and affiliated societies and members of their parties will be held in the evening.

Subsequent meetings of the Society and meetings of the Council, unless otherwise stated, will be held in the Students' Observatory, Berkeley, Cal.

Tuesday, August 3rd—

9 A. M. Meeting of the Council.

10 A. M. Joint session with Section A of the A. A. A. S. and the American Mathematical Society, presided over by the vice-president of Section A, to hear addresses by Professor GEORGE E. HALE and Professor C. J. KEYSER. Section B of the A. A. A. S. and the American Physical Society have been invited to attend this session.

2 P. M. Joint meeting with the Astronomical Society of the Pacific. For a part of this meeting, the President of the A. S. P. will preside, during which time the Bruce Gold Medal of the A. S. P. will be presented, and papers by men who are members of both astronomical societies will be read.

Wednesday, August 4th—

The A. A. A. S. and affiliated societies will make an all-day excursion to Stanford University. If there is press of papers a session for their presentation may be held there.

Thursday, August 5th—

9 A. M. Meeting of the Council.

10 A. M. Meeting for the presentation of papers. Nominating ballots for officers.

2 P. M. Papers.

Friday, August 6th—

Excursion to the Lick Observatory, to include members of the A. A. S. and Section A of the A. A. A. S.

There will be no formal evening sessions of the Society. There are general sessions of the A. A. A. S. for addresses or formal lectures on all evenings except Wednesday, which is therefore available for dinners, reunions, etc., as may be arranged.

A conversazione for the informal exhibition of photographs, lantern slides, and other illustrations of astronomical work will be arranged, the time to be announced on the detailed program for the meeting.

It is announced in *Nature* that the *Gazette Astronomique*, the monthly bulletin of the Antwerp Astronomical Society, publication of which was necessarily discontinued last autumn, is to be published in England if sufficient financial aid is given. The first number of the new series has, in fact, been issued.

We regret to record the death, on March 27, 1915, of Lady MARGARET LINDSAY HUGGINS. From the date of their marriage in 1875, she was an enthusiastic collaborator with the late Sir WILLIAM HUGGINS in his fruitful spectroscopic researches. "For thirty-five years they labored together and the numerous papers bearing their names as joint-authors commanded the admiration of the scientific world."

Dr. CARL G. ABBOT, Director of the Astrophysical Observatory of the Smithsonian Institution, has been elected a member of the National Academy of Sciences.

Dr. S. A. MITCHELL, Director of the Leander McCormick Observatory of the University of Virginia, has been appointed Ernest Kempton Adams Research Fellow by the trustees of Columbia University.

OFFICERS OF THE SOCIETY

Mr. R. G. Aitken	*President*
Mr. S. D. Townley	*First Vice-President*
Mr. J. Costa	*Second Vice-President*
Mr. F. V. Cornish	*Third Vice-President*
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NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished free of cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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WILLIAM WALLACE CAMPBELL.

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ADDRESS UPON THE PRESENTATION OF THE BRUCE GOLD MEDAL TO DR. W. W. CAMPBELL.[1]

By Russell Tracy Crawford.

"Every career has its aspirants, who pay their respects to those who have reached the goal." And so we are gathered here on this occasion to pay our respects to one who has reached a place among the eminent in astronomy. The Bruce Gold medal is awarded by this Society for "distinguished services to astronomy," and the statutes relating to its bestowal require that, at the presentation, an account shall be rendered of these distinguished services. That Dr. Campbell has rendered such services no one the least conversant with the science of astronomy will question. If, perchance, there should be a doubter, I advise such a one to read our Medalist's recent book, "Stellar Motions," and "forever after hold his peace." Therein is to be found a wealth of material and deductions from his years of work with the spectrograph, a most powerful instrument in his hands.

"Success," wrote Victor Hugo, "is a very hideous thing, and its resemblance with merit deceives men." In the award of the Bruce Gold Medal deceit can play no part, as can be realized when the method of making the selection of medalist is known. Here success and merit must go hand in hand. You may be sure that anyone who attains success thru anything but merit can never receive this medal.

To Dr. Campbell have been awarded four other medals, viz., the Lalande in 1903, the Royal Astronomical Society in 1906, the Draper in 1906, and the Janssen in 1910. The address dent W. H. MAW in awarding the Gold Medal of the Royal Astronomical Society is an excellent account of our Medalist's distinguished services up to 1906. In my account I shall, therefore, simply summarize what President MAW has said so well, and dwell in particular only on matters that have been developed since 1906.

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[1] Delivered at the joint meeting of the American Astronomical Society and the Astronomical Society of the Pacific, at Berkeley, Tuesday afternoon, August 3, 1915.

First and foremost are mentioned Dr. CAMPBELL'S determinations of stellar velocities in the line of sight, and his work on spectroscopic binaries. He is easily recognized as a leader in these investigations. The improvements and refinements made in the spectrograph by himself and his colleagues have led to such a degree of accuracy in his radial velocity determinations that Dr. CAMPBELL has been able to detect a variation of velocity with the Mills' spectrograph of an amount smaller than the probable error of a determination with most other instruments. President MAW says in this connection, "The development of this branch of spectroscopic astronomy has thus only been secured by the gradual introduction of various instrumental refinements, combined with the recognition of the sources of error, and the exercise on the part of the observers of care and skill of the very highest order."

In April, 1905, Dr. CAMPBELL issued his first catalog of spectroscopic binaries. In the words of President MAW, "a catalog which is in itself ample evidence of the importance of the work done by our Medalist."

By February, 1906, the radial velocities had been determined of about 500 stars at the Lick Observatory, and of about 200 stars at the D. O. Mills Observatory in Chile. "The whole of this extensive and most important work has been inaugurated by our Medalist, and carried out—much of it by himself—in accordance with the program he had drawn up," writes Dr. MAW. And I may add that to date this output has been practically doubled.

An interesting by-product of this work was Dr. CAMPBELL'S discovery in August, 1899, of the triple character of *Polaris*.

One of the several problems Dr. CAMPBELL had set for solution in connection with his radial velocity work is that of finding the Sun's way. In 1901 he had the results from 280 stars with which to make a first rough determination. He found the Sun to be traveling with a velocity of 19.9 kilometers per second toward the point in the sky $\alpha = 277^\circ.5$ and $\delta = + 20^\circ$. This declination differs about 15° from that ascribed by NEWCOMB. Dr. CAMPBELL attributed this to the fact that his stars were not uniformly enuf distributed over the sky. He then realized that he must have the radial velocities of stars in the southern hemisphere which could not be reached from the Lick Observatory. This led him to the establishment of the D. O. Mills Observatory in Santiago, Chile. "The organization of this expedition, says President MAW, "may well be cited as a splendid example of the thoroness and vigor with which our Medalist attacked an important problem." In 1910 he had available the results from 1047 stars fairly well distributed with respect to the two hemispheres from which he deduced a velocity of — 17.77 kilometers per second toward the point $\alpha = 272^\circ\ 0'$, $\delta = + 27^\circ\ 26'$. In March, 1911, the elements of the solar motion were re-determined according to a rather extensive program. (Cf. *Stellar Motions*, pg. 209.) Based upon 1193 stars, $V_0 = -19.5^{km}$, $\alpha = 268^\circ.5$, $\delta = + 25^\circ.3$. From his various solutions wherein the stars were grouped according to spectral type Dr. CAMPBELL concludes, "The resulting velocity of the solar motion, V_0, appears to be a function of the spectral class of the stars upon which it rests, at least as far as the brighter stars are concerned."

Another interesting result from these investigations is the relation between the velocity of a star in space and its brightness. Of Dr. CAMPBELL's earlier work President MAW calls attention to his investigations of the Wolf-Rayet stars, and numerous spectroscopic results of minor importance.

To organize and carry thru to a successful conclusion an eclipse expedition requires a mind that, like the chess master's can see many moves ahead. Dr. CAMPBELL's experiences on numerous journeys to observe eclipses have now put him into a position to organize such an expedition so that every screw, nail, board, lens, can of meat, or anything else that may be needed is fully provided for; just what is necessary, and nothing that is not necessary. When one reads his charming account of the expedition to Flint Island one realizes how very much of the success of eclipse observing is due to this genius for organization. Those who have been fortunate enuf to hear our Medalist lecture about such an expedition have been presented with many interesting side-lights concerning them which bring out, even more clearly than his written accounts, his forethought in planning and resourcefulness in carrying out his program. In addition to this power of organization there stand to his credit many ingenious arrangements for observing eclipses. To quote again from President MAW, "It is, in fact, impossible to overrate the importance of the influence which our Medalist has exercised on the eclipse expeditions which have during recent years been sent out from the Lick Observatory; and probably only those who have taken part in such expeditions can fully appreciate his powers of organization, and his skill and resourcefulness in devising special lines of research and instrumental means for rendering such researches practicable."

President MAW calls attention to our Medalist's researches in the spectra of nebulæ, the orbit and parallax of *Sirius*, spectra of comets, and spectroscopic characteristics of temporary stars.

One of our Medalist's greatest contributions to the cause of science is in his upsetting the old idea that, as Sir G. H. DARWIN stated, "A mere catalog of facts, however well arranged, has never led to any important scientific generalization." This theme has been so well developed by Professor TURNER in his Presidential Address[1] before the B. A. A. S. in 1911 that I shall not dwell further on it here.

When Dr. CAMPBELL commenced his wonderful series of observations for radial velocities he had in mind the solution of four or five definite problems. But he never dreamed, I am sure, that they would ultimately lead him to make the astounding discovery that the older a star is, the greater is its speed. Of this Professor EDDINGTON writes, "We may well regard this relation of age and velocity as one of the most startling results of modern astronomy."

Averaging the velocities of stars of the same spectral type (according to SECCHI's classification), Dr. CAMPBELL found this progression and announced it in the Silliman lecture of

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[1] *Science*, Sept. 15, 1911.

January 31, 1910. His words are:[1] "The progression of average velocity with advancing spectral type is clear and unmistakable." Then to be more convincing he tells us that:[2] "Returning to Mount Hamilton on February 24, 1910, I had the velocities with reference to the stellar system tabulated on the basis of the Harvard classification of spectra, as follows:—

Spectral Classes	Number of Stars.	Average Radial Velocities.
O and B	141	8.99^{km}
A	133	9.94
F	150	13.90
G and K	520	15.15
M	72	16.55
Nebulæ (KEELER)	13	23.4

The increase of stellar velocity with advancing type was seen to hold on the Harvard classification, as well as for the Secchi classification upon which the discovery had been made.

It was a surprise to find the average velocity of the thirteen nebulæ, as observed by KEELER, in excess of the averages for the stellar spectral types. This may or may not indicate that the number of nebulæ available is too small to serve as a basis for averages. If from the list of thirteen nebulæ we remove the *Orion* nebulæ, which has radial velocity nearly zero, the average residual radial velocity for the remaining twelve nebulæ is in excess of 25^{km}. Here we may have evidence of great strength and importance in support of a hypothesis that the planetary nebulæ have been formed from stars thru processes arising from collisions with or close approaches to other massive bodies. The zero velocity of the *Great Nebula in Orion* is not out of harmony with the hypothesis."

This startling and important discovery has made necessary a reorganization of the lines of thought in stellar evolution and cosmogony. Its effects are far-reaching.

DARWIN demanded, as Professor TURNER points out, a theory as a necessity for the advance of science. Here, however, we have a weighty advance of science and no theory. A theory is now to be sought to account for the observed fact. I am sure Dr. CAMPBELL thinks he has advanced no theory, but a reading of his *Stellar Motions* will show that he is not lacking in ideas on the subject, as he naïvely asks a few pertinent questions. Let me quote his words,[1] "It is not easy to explain why the velocities of stars should increase with their effective ages, for we are accustomed to think of all matter as equally old gravitationally. Why should not the materials composing a nebula or a Class B star have been acted upon by gravitational forces as long and as effectively as the materials in the Class M stars? Are stellar materials in the ante-stellar state subject to NEWTON's law of gravitation? Does gravitation become effective only after the processes of combination are well under way? Is it possible that the gaseous matter composing a nebula is acted upon as effectively by radiation pressure as by gravitational attraction? The observed fact of the dependence of stellar velocity upon the spectral class is so new that these comments and questions make no pretentions to the status of a solution; but I am unable to suggest any other directions in which we should seek for the explanation."

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[1] CAMPBELL, *Stellar Motions*, page 206.
[2] *Ibid.*, page 207.

Another interesting and important result that our Medalist has arrived at, based upon his valuable radial velocity data, is the relation between the distances of the components of a binary system, the eccentricities of their orbits, and their age. "A study of the orbits of spectroscopic binary stars has established that the component stars in a system whose spectrum indicates early age are relatively very close together, requiring very short periods of revolution, and that the orbits are nearly circular. In systems whose spectra show them to be of greater effective ages, the distances separating the components are successively greater, on the average, and their orbits are more eccentric. The observed facts on the subject are fully confirmative of existing mathematical theories of the evolution of double star systems."

In discussing the question of parallax and proper motion as related to spectral types Dr. CAMPBELL comes to the conclusion, "That the scale on which the universe of brighter stars is constructed is apparently a great deal larger than we had supposed." And thus he enlarges our horizon, so to speak, and calls attention to the urgent need of still more radial velocity determinations to help in the solution of the many great problems relating to the stellar universe, not a few of which, I may add, owe their inception to the genius of our Medalist.

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[1] *Stellar Motions*, page 216.

In pleading for further observations he also urges the attainment of greater accuracy. In this connection he opens our eyes in regard to the character of our stellar neighbors, pointing out that it is quite probable that our system of one large central body attended by several very small masses is an exception, and not the prevailing type of system. If an accuracy could be attained which would reveal a variation of 0.03^{km} per second, the variation of speed of the Sun about the center of gravity of the solar system could be observed by an observer on another system. To quote from *Stellar Motions*, pg. 281, "An observer, favorably situated in another system, provided with instruments enabling him to measure speeds with absolute accuracy, could detect this variation, and in time say that our star is attended by planets. . . . As the accuracy attainable improves with experience, the proportional number of spectroscopic binaries discovered will undoubtedly be enormously increased. There is a possibility that the stars attended by massive companions, rather than by small planets only, are in a decided majority; . . . This is not a casual and passing comment. We do not possess a shred of positive evidence that any other star than our own is attended by small planets: we seem powerless at present to obtain any evidence in favor of or against their existence; and the prevailing belief that planets exist in other systems rests upon analogy to the solar system. We *have* the evidence of visual and spectroscopic binary stars that other systems with two or more massive central bodies are extremely common."

In his book *Germany and the Germans*, Price Collier has written, "The real test of successful organization is the thoroness of the thinking behind it; on the other hand, the only test of the thinking is the success of the thought in actual execution." When we consider the eminently successful work turned out from the Lick Observatory we have before us the evidence that our Medalist has rendered distinguished services to astronomy not only as a scientist, but also as a capable director of a great observatory. Too often the taking over of executive responsibilities has been a detrimental handicap to the individual scientist. Happily this has not been the case with our Medalist. VICTOR HUGO speaks of "a contagion of idleness." There is also a contagion of activity. And so Dr. CAMPBELL has rendered further great services to astronomy in the inspiration he has imparted to those working with him.

In his Sigma Xi address at the University of Illinois, delivered May 4th of this year, Professor GEORGE OTIS SMITH says, "A statesman is defined as a politician who has died. . . . Too often we are tardy in our recognition of the worth of men and also of the significance of events." Fortunately we, today, are not too tardy in our recognition of the worth of our Medalist. And I know that it is a matter of deep gratification to us all that we are gathered here to pay our respects to him.

Dr. WILLIAM WALLACE CAMPBELL, Director of the Lick Observatory, efficient executive, great astronomer, eminent scientist, it is with greatest pleasure that, on behalf of the Astronomical Society of the Pacific, I now present to you this beautiful medal with full knowledge that the Society, in thus honoring you is honoring itself in inscribing your name on the roll of illustrious recipients of the Bruce Gold Medal.

THE WORK OF A MODERN OBSERVATORY.[1]

By George Ellery Hale.

We have been fortunate enuf to live in a golden age of science, an age rich in discoveries of instruments, methods and ideas readily applicable in the domain of astronomy. Each one of us, from the amateur, whose chief equipment may consist of an unquenchable thirst for knowledge, to the endowed investigator, lacking in no material means, may profit by the extraordinary advances of recent years. Half a century ago the equatorial telescope and meridian circle, with clock and micrometer, were the sole instruments of the observatory. They were used mainly to measure the positions and motions of the heavenly bodies, and altho the foundations of astrophysics had been laid long before, the means available for the erection of its superstructure were few and insignificant when compared with those we now enjoy.

The two chief factors in the new advance appeared, curiously enuf, within the same decade. The sensitive plate, first employed by Daguerre in 1839, was utilized at the Harvard Observatory for stellar photography in 1857 and applied to the registration of the solar image at Kew in the following year. The spectroscope, chief instrument of the student of inorganic evolution, first proved its worth almost simultaneously with the publication of the *Origin of Species* in 1859, when Kirchhoff and Bunsen determined by its aid the chemical composition of the Sun. Bond's experiments in stellar photography at Harvard had been made with the wet collodion plate, but in 1876 Huggins first applied dry plates to the photography of stellar spectra. To-day comparatively few astronomical observations are made visually. The spectroscope, once a minor accessory of the telescope, is now more properly regarded in some classes of work as the primary instrument, with the telescope as its indispensable auxiliary. Originally a simple laboratory appliance, suited only for qualitative purposes, it has

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[1] Address delivered at the joint meeting of Sections A and B of the American Association for the Advancement of Science, the American Astronomical Society, the American Mathematical Society, and the American Physical Society, at Berkeley, Tuesday forenoon, August 3, 1915.

d into a measuring instrument of extraordinary flexi-
y and power, yielding results which surpass in precision the most refined measurements of visual astronomy.

Supplementing and in some cases superseding the spectroscope, there have arisen the interferometer in its various forms, the MICHELSON echelon and the LUMMER-GEHRCKE parallel plate, each applicable with advantage to certain kinds of light analysis. Instruments of surprising sensitiveness, including the thermopile, the bolometer, the radiometer, the radiomicrometer, and the selenium and photo-electric cell, have brought to knowledge radiations far beyond the range of the eye or the photographic plate, and disclosed stellar variations in brightness too minute for former devices to reveal. At the same time telescopes have increased greatly in aperture and in optical and mechanical perfection, while new photometers, clocks and other auxiliaries of various kinds have led to more refined astronomical measurements, which have reached their highest precision thru the improvement of the photographic method. For the study of astronomical photographs, a large class of special machines has been developed, ranging from the measuring microscope to KOCH's registering micro-photometer, which involves an ingenious application of the photo-electric cell.

Within the brief limits of this address I cannot hope even to enumerate more than a small fraction of the many appliances which the astronomer now has at his disposal. But I must mention here that large category of laboratory apparatus, including the electro-magnet, the vacuum tube in its many forms, the electric furnace and the long array of similar devices which the discoveries of ZEEMAN, STARK and other physicists have rendered of fundamental importance. I may also remind you of the astronomical significance of discoveries in radio-activity, theories of the structure of the atom, the laws of spectral series, and a host of other advances, which have so greatly enlarged the scope of our inquiries.

The combined effect of these developments has been, not merely to multiply our means of research, but to modify our point of view, and to bring it much more nearly into coincidence with that of the physicist. Many physical and chemical phenomena have been recognized in the Sun and stars before they were known in the laboratory. Thus helium, first produced in the laboratory in 1895, was discovered in solar prominences in 1868. Nebulium, the predominant constituent of nebulæ, has not yet been found on the Earth. The effects of the selective absorption of light, which lie at the basis of spectrum analysis, were first interpreted by observations of the solar spectrum. Changes in the relative intensities of spectral lines due to reduction of temperature were first observed in sun-spots. Again, certain experiments beyond the range of the laboratory can be performed with the aid of celestial bodies. Thus, in order to help answer the question whether all large rotating bodies are magnets, we may examine the light of that immense rotating sphere, the Sun. And so I might go on to illustrate the advantage to the chemist or the physicist of studying astronomical objects, which frequently present facilities for tests or experiments difficult or impossible under terrestrial conditions.

But the converse view is the one I wish to emphasize: namely, the importance to the astronomer of interpreting celestial phenomena by means of laboratory experiments, where the exact conditions are known and are under perfect control. No method of research is more satisfactory than this, for none goes so directly to the heart of the question or eliminates more completely the danger of error.

In undertaking to deal with what I may call the laboratory method in astronomy, let me invite your attention to three phases of the subject. These involve:—

(1) The adaptation and use in the observatory of various laboratory instruments.

(2) The modification of the design of astronomical instruments so as to permit solar and stellar images to be studied under laboratory conditions.

(3) The imitation and interpretation of celestial phenomena by laboratory experiments.

In each case my treatment must be very fragmentary, based upon certain typical examples which serve to illustrate the point in view, but making no attempt to cover the ground exhaustively. In choosing my illustrations I have frequently been guided by a desire to indicate opportunities for work with small and inexpensive equipments, such as any amateur may possess. In these days of great telescopes there is danger that an erroneous impression regarding the possibilities of limited resources may prevail. As a matter of fact, these possibilities are enormously greater than ever before, and no one who realizes the true state of affairs need fear that his means, however simple, are inadequate to advance knowledge. A great telescope, tho desirable or even essential for many purposes, is by no means required for much work of the highest class. Indeed, some of the discoveries I shall mention as the product of smaller instruments are quite beyond the reach of the largest telescope unless it be equipped with special auxiliaries.

(1) *New Instruments from the Physical Laboratory.*

Few recent illustrations of the advantages which may follow the intelligent application of physical methods in astronomy are more striking than that afforded by the selenium cell. The sensitiveness of selenium to light, which reduces its electrical resistance, has been known for many years. But it remained for STEBBINS, working with a standard 12-inch telescope at the University of Illinois, to demonstrate that important astronomical discoveries may result from the use of this principle. Better than selenium, and now adopted in its stead, is the photo-electric cell perfected by ELSTER and GEITEL. This consists of a clear metallic surface of sodium, potassium, rubidium or cæsium, sealed within a glass bulb containing helium at low pressure. When exposed to light the metallic surface gives off negatively charged particles and thus acquires a positive charge easily measured with a delicate electrometer.

Here is a photograph[1] of Dr. STEBBINS' telescope with the cell in place. Applied to a star *(δ Orionis)* suspected of variability, but showing no changes appreciable to the eye, the cell has yielded measures represented by this intensity curve. In this way a large new class of variable stars, formerly regarded as invariable, is rendered available for study. Conspicuous among these are many spectroscopic binaries, whose orbital motions have been revealed by the spectrograph. It is unnecessary to say that a means of measuring their corresponding fluctuations in light, previously beyond reach in the vast majority of cases, will be of great service to the astronomer. Obviously the photo-electric cell can be applied to many other astronomical and physical purposes, and we may confidently look to it for many discoveries in the future.

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[1] Here and thruout his address Dr. HALE illustrated his points with lantern slides. The experiments described in the last section of the address were beautifully carried out in the lecture room.—EDITORS.

Another powerful weapon of attack was disclosed when LANGLEY invented and applied the bolometer in 1880. If a thin wire, say of steel or platinum, is heated, its electrical resistance is altered. Suppose this wire is made to serve as one arm of the delicate device known as Wheatstone's bridge, used in every electrical laboratory for resistance measurements. When properly balanced, and employed with an exceedingly sensitive galvanometer, the bolometer is capable of detecting a change in temperature of less than a millionth of a degree. Its extreme sensitiveness to radiation led LANGLEY to explore the invisible infra-red spectrum with its aid. Thus he disclosed an extensive region, unknown to the eye or the photographic plate, and fully ten times as long as the entire visible spectrum from red to violet. Glass is as impervious as steel to the longer waves of the infra-red, and rock-salt lenses and prisms must be used to transmit them. In its perfected form, as employed by ABBOT, the bolometer has become an automatic recording instrument of perfect reliability, serviceable in a score of ways to the student of astrophysics. Already, in conjunction with an improved pyrheliometer, it has demonstrated the Sun to be a variable star, and measured its fluctuations in heat radiation.

The detection and measurement of the almost infinitesimal heat which reaches us from the stars is a task of very recent achievement, carried to a high degree of success by COBLENTZ at Mount Hamilton in 1914. NICHOLS, using a radiometer sensitive to the light of a candle five miles away, (assuming no atmospheric absorption) had measured the heat radiation of *Arcturus* and *Vega* at the Yerkes Observatory in 1900. PFUND improved materially on his results, and COBLENTZ has now ished the remarkable task of measuring the heat from beyond the limit of naked-eye visibility.

The apparatus employed for this work is an improved form of thermopile, an instrument which dates from 1830, when NOBILI and MELLONI constructed from strips of antimony and bismuth a heat-measuring device ten times as sensitive as the best thermometer of the day. The thermopile of COBLENTZ, consisting of a very small bismuth-platinum junction supported in a vacuum chamber at the focus of the three-foot mirror of the Crossley reflector, would give a galvanometer deflection of 1 mm. when exposed to the radiation of a candle 53 miles away, if there were no atmospheric absorption. Dr. COBLENTZ believes that the sensitiveness of the thermopile-galvanometer combination can be increased sufficiently to detect the radiation from a candle 500 miles away, if employed in conjunction with a seven-foot mirror. Under such conditions work of great value could be done on the spectral energy curves of stars.

So far our attention has been concentrated upon certain electrical devices which act like super-senses, applicable where other means at our disposal are sluggish or wholly inert. Let us now turn to another group of instruments, which may be used in lieu of the most powerful spectroscopes for the refined analysis of light.

MICHELSON'S interferometer has been applied with success in a score of different fields. It serves to render visible the twisting of a massive steel bar by the fingers, to test the relative motion of the Earth and the ether, or to measure the length of the international meter in terms of that invariable unit of reference—the light-wave. From the point of view of the spectroscopist one of its greatest services is the converse measurement of the absolute wave-length of light.

In this field the interferometer of FABRY and PEROT is also of the highest importance. In the extremely simple and convenient form of the *étalon*, best consisting of two plates of lightly silvered fused quartz held perfectly parallel at an invariable distance of a few millimeters by short bars of invar, it now plays a leading part in high precision spectroscopy. The circular fringes produced when the light of mercury vapor is allowed to fall on an étalon are of great beauty, representing not only the chief lines but also their faint satellites in the form of companion fringes. The slightest change in the wave-length of the light is shown by expansion or contraction of the fringes. So sensitive is this interferometer that the Doppler effect can be demonstrated experimentally by its aid. It is only necessary to provide a wheel with projecting paddles of white paper, and illuminate it with green mercury light when it is spinning at high velocity. The motion of the paddles toward or away from the observer will be indicated by a slight change in the diameter of the fringes, due to a corresponding change in the effective wave-length of the light reflected back from the moving paddles. Thus the very method which we utilize with the spectroscope for the study of the Sun's rotation or the radial motions of stars can be experimentally illustrated in the laboratory.

Time fails me to describe FABRY's beautiful investigation with the interferometer of the moving gases in the *Orion* nebula, or to speak of those ingenious instruments, the echelon grating of MICHELSON and the LUMMER-GEHRCKE parallel plate. But I cannot fail to mention the remarkable advances recently made in the ruling of diffraction gratings, the chief reliance of the spectroscopist in almost every class of laboratory and observatory work demanding high dispersion. A century ago FRAUNHOFER of Munich, after making the first gratings from wires stretched between two screws of very fine pitch, succeeded in ruling parallel lines on glass at the rate of 400 to the millimeter and even finer. With these he successfully observed the dark lines of the solar spectrum. RUTHERFORD's ruling machine, constructed by CHAPMAN in 1879, yielded gratings of excellent quality which were applied by RUTHERFORD, DRAPER, YOUNG and others to the study of the solar spectrum. A still greater advance was made in 1882 and later, when ROWLAND's large concave gratings suddenly advanced spectroscopy from the qualitative to the quantitative stage by rendering possible measurements of the highest precision. With ROWLAND's reconstructed machine ANDERSON has recently ruled gratings of extraordinary perfection, having a resolving power fully twice that predicted from theory.

Finally, to crown this long list of achievements, MICHELSON has recently ruled a ten-inch grating having about 622 lines to the millimeter, which gives superb resolution even in the eighth order.

We must now leave this phase of the subject, tho it is far from exhausted, and consider how we may acquire some of the chief advantages of laboratory conditions in astronomical spectroscopy.

(2) *Laboratory Conditions in Work with the Telescope.*

I had hoped, when first outlining this address, to include in it a brief sketch of the development of the astronomical telescope. It would have been interesting to describe the rise and progress of the refractor, so long delayed by the absence of suitable optical glass, and to trace the origin of the reflector, its curious decline during the second half of the last century, and its remarkable development in recent years. It might have been profitable also to emphasize those sterling qualities of the refractor which so firmly maintain its place in the observatory, in spite of the advance of its powerful rival. Its convenience of manipulation, surprising insensibility to temperature change, and large field of view are not shared by the reflector, tho for perfect achromatism and light-gathering power per unit cost the latter stands alone. Both instruments therefore have important places to fill, and it is merely a question of apportioning to each its most suitable field of observation. FOR BURNHAM'S, AITKEN'S, and HUSSEY'S observations of double stars, BARNARD'S measures of faint satellites and other difficult objects, FOX'S and SLOCUM'S photographs of solar prominences, RITCHEY'S photographs of the Moon, the photographic determinations of parallaxes so ably initiated by SCHLESINGER, and many other classes of work the Lick and Yerkes refractors, which we may take as examples, have proved of immense value. And while large reflectors might now be preferred to them for the photographic investigation of the spectra of the fainter stars, the splendid spectroscopic work of CAMPBELL, FROST and others with these telescopes show how efficient they are in this department.

The discussion of telescopes into which I am so seriously tempted to fall would give due credit to the wide field of the portrait lens, utilized so effectively by PICKERING in cataloging the spectra of several hundred thousand stars and by BARNARD in his photographic studies of the Milky Way. The advantage of the photographic correction for the two-lens refractor, so clearly exemplified in SCHLESINGER'S recent parallax work with the BRASHEAR 30-inch at Allegheny, would also demand consideration; but in spite of its effective recognition in this instance, it is fortunate that large visual refractors are still available for those investigations in which the eye and micrometer are indispensable. In fact, the entire discussion would illustrate how the recognition and utilization of various optical and mechanical possibilities have given us a whole series of telescopes, each adapted for work in certain fields.

Of the types of telescopes thus developed there is one which falls within the subject I have undertaken to sketch. This is the instrument which brings a solar or a stellar image into a laboratory for study by spectrographs or other apparatus too large or too delicate to serve as attachments to moving telescope tubes.

The solar spectroscope, as first used by KIRCHHOFF and BUNSEN, was a fixed laboratory instrument fed with sunlight by a heliostat. Later it became an attachment of the equatorial refractor, which permitted its application to the study of sun-spots, prominences and other details of the solar image. In this form it grew toward a maximum focal length of about 3½ feet, limited by the carrying capacity of the telescope and other considerations. ROWLAND'S researches with concave gratings of 21 feet focal length revolutionized laboratory spectroscopy, but it was obvious that spectroscopes of equal power could not be attached to a moving telescope. Fixed telescopes giving a large and sharply defined solar image thus became necessary.

These involve the use of a heliostat or coelostat, sending a beam of sunlight in a fixed direction, usually horizontal or vertical. In the latter case, the coelostat, second mirror and object-glass (here of 150 feet focal length), may be mounted at the summit of a steel tower, while the spectrograph, of 75 al length, stands in a well excavated in the earth beneath it. The great stability of the spectrograph and the constancy of temperature of the grating at the bottom of the well, are among the chief advantages of this form of instrument. The solar image, over 16 inches in diameter, is thus available for study under the best of laboratory conditions.

The advantages of solar spectrographs of great focal length are easily illustrated. Four photographs of the solar spectrum, taken with spectrographs of 42½ inches, 18 feet, 30 feet and 75 feet focal length respectively, show striking differences in the separation of lines. This is partly due in the last step (30 feet to 75 feet), to the use of a MICHELSON grating in place of the smaller ROWLAND grating employed with the first three spectrographs. But a comparison of the first three spectra will show that the improvement is mainly due to the gain in linear dispersion and photographic resolution effected by increasing the focal length of the spectrograph. Details hopelessly confused in the small scale spectra by the blending of lines are plainly apparent under the higher linear dispersion, and the precision of differential measurements of the finer lines is fully proportional to the increase in scale.

These large spectrographs are of the auto-collimating type, i. e. the rays are returned by the grating thru the collimating lens, which thus serves also to form the image of the spectrum near the slit. A spectrograph which has some optical advantages is that in which the collimator and camera are inclined at an angle of from 25° to 60°, in order to utilize the increased dispersion thus obtainable.

The gain effected by high dispersion in solar spectroscopy, which has recently been utilized in many classes of work, naturally suggests a similar step in stellar spectroscopy. Here, however, the conditions are essentially different, partly on account of the faintness of the stars, and also because complete success has already been achieved, at least in the measurement of stellar motions, with spectrographs of moderate dimensions attached to equatorial telescopes. It is astonishing to think how much has been accomplished in this field by CAMPBELL and his colleagues since the Mills spectrograph entered upon its pioneer labors with the Lick telescope in 1896. From the very outset beautifully sharp photographs of stellar spectra and velocity measures of the highest precision have been obtained with this instrument, which in its perfected form still continues its work on Mount Hamilton, supplemented by a similar instrument in the southern hemisphere. No method of improving on the results obtained with these spectrographs is yet in sight, and the high dispersion spectrograph which I am about to mention is intended for work of another kind.

In the study of the physical nature of stars we must deal with problems like those of solar physics, in which extremely minute displacements of spectral lines may be interpreted as the effect of the pressures and motions of vapors lying at different levels in stellar atmospheres. Valuable results in this field have already been obtained by ADAMS with the 60-inch Mount Wilson reflector, and the 100-inch telescope mounting now under construction has been designed so as to permit the use of a stellar spectrograph of from 30 to 50 feet focal length. This is to be mounted on a massive pier in a constant temperature chamber, so that the exposures may be continued for several successive nights, or until an impression of the highly dispersed and therefore feeble spectrum has been obtained.

§ 3. *The Imitation of Celestial Phenomena by Laboratory Experiments.*

We have now glanced at two phases of the laboratory method in astronomy, involving, on the one hand, the adaptation of various physical instruments for use with the telescope, and, on the other, the modification of telescope design in order to bring solar and stellar images into constant temperature laboratories. Let us next turn our attention to a no less important possibility: the interpretation of celestial phenomena by laboratory experiments. Many examples of such work might be given, but I have ventured to choose one from recent experience, which is easily illustrated, and may have some suggestive value, especially to those who lack extensive instrumental equipment. I refer to a series of simple vortex experiments bearing on the nature of sun-spots and flocculi.

In order to make these experiments intelligible I must first recall the circumstances under which they were developed and the hypothesis they are intended to test. If we photograph the Sun with a spectroheliograph which excludes from the photographic plate all light except that of the red line (*Hα*) of hydrogen, we find what appear to be vortex phenomena associated with sun-spots. In fact, we seem to be looking into immense whirlpools, which sometimes sweep clouds of hydrogen into the spots at high velocities. This leads us to infer, as Sir JOHN HERSCHEL and FAYE did long ago, that sun-spots may be closely analogous to tornadoes in the Earth's atmosphere. Modern electrical experiments tell us that there must be many electrically charged particles in the Sun, and these would produce a magnetic field if whirled in a vortex. From this point of view a sun-spot resembles a helix of wire, thru which an electric current is flowing. But how are we to find whether a magnetic field is actually present in the spot?

Fortunately ZEEMAN has shown us how to recognize the very characteristic effects of magnetism on light. We pass a spark between two rods of iron supported between the poles of a magnet. The lines of the iron spectrum, ordinarily single, are split into three or more components the moment the current is sent thru the magnet coils. Hence the iron lines should behave similarly in a sun-spot. We photograph the spot spectrum, and find the lines to be split into triplets, quadruplets, quintuplets, etc., the number of components being the same, line for line, as in the laboratory. These are polarized in a most characteristic way, so that either side line of a triplet can be cut off at will by a Nicol prism and quarter-wave plate.

Here is an iron triplet in the sun-spot, which also turns out to be triple in the laboratory. We apply the polarization test, and cut off its components at will. Next to it is another iron line, which appears as a quadruplet both in laboratory and spot and answers equally well to the polarization test. So we may go on, comparing in spot and laboratory all the lines of iron and other elements, measuring the strength of the magnetic field in different parts of the spot and at various levels above it, and determining the inclination of the lines of force to the line of sight.

These magnetic experiments, which are supported by EVER-

SHED's and ST. JOHN's spectroscopic observations of the whirling vapors in spots, justify the assumption that sun-spots are vortices. Let us try to indicate by some simple experiments how such vortices may arise and what forms they may assume.

Everyone has seen a whirling dust-storm and knows by hearsay, if not by experience, of the destructive tornado or the waterspout. It is easy to imitate these phenomena by an experiment due to WEYHER. Here is a shallow cylindrical box, with radial vanes, mounted on a vertical axis. When spun at high velocity, it draws up the air from below, and produces a very passable imitation of a waterspout rising from a pan of steaming water. More plainly visible to an audience, and more closely analogous to whirling prominences sometimes observed on the Sun, is this "firespout" produced by spinning our disk above a flame rising from cotton saturated with gasoline.

In the Earth's atmosphere any column of air, carried rapidly upward by convection, begins to whirl and becomes a columnar vortex. In the Sun, on account of its high temperature, the ascending convection currents are much more numerous and violent, and similar vortex phenomena must be of frequent occurrence. Here, for example, is an illustration of vortex motion in a solar prominence, as seen at the edge of the Sun. The analogy with a terrestrial dust whirl is apparently very close, and we may advantageously push our inquiry further.

Sun-spots, which lie at the base of the solar atmosphere, probably originate within the photosphere. It has been shown by FOX and others that they are invariably preceded by eruptions, which represent hot masses of gas rising rapidly from the interior to the surface. Thus a columnar vortex would be set up, which might resemble a waterspout if we could see it below the photosphere.

So far we have been thinking of single spots. But sun-spots have a remarkable tendency to appear in pairs, the members of which are of opposite magnetic polarity, i. e. their electric vortices are whirling in opposite directions. Can we throw any light on this peculiarity by laboratory experiments?

Here is a flexible spiral spring of closely coiled brass wire, with some disks of wood threaded on it. We hang it vertically in a tank of water and spin it rapidly with an electric motor.

The water close to the wooden disks is set whirling by the friction, and we have a columnar vortex resembling a single sun-spot. At low speeds this vortex remains nearly vertical, but as the speed increases it begins to bend, its lower end rising toward the surface until finally it assumes a semi-circular form, and moves forward thru the water at right angles to its plane, thus rotating about the shaft of the motor. It is interesting to watch the depressions and whirls in the water before the free end reaches the surface. These correspond in the hypothesis to the incipient spots which frequently form and disappear at the incomplete end of a bipolar sun-spot group.

But why does the semi-circular vortex rotate, and is there any analogous motion of sun-spots? Here is a box containing smoke. If I strike it sharply a smoke-ring is formed and moves rapidly thru the air. This familiar experiment may be repeated in a much more effective manner described by MACH. If a little colored liquid is forced from a tube in water a vortex ring will be formed and move thru the tank. The structure of this ring is beautifully shown by these photographs, which are very easily made. Let me call your attention to two points of importance. Note, in the first place, that as the outer circumference of the vortex ring is naturally greater than its inner circumference, it will be more retarded by friction with the surrounding water. Hence the ring will move forward in a direction which corresponds with the direction of rotation of the fluid at its inner edge. It was mainly for this reason that our flexible columnar vortex, when turned up into the form of a semi-circular vortex ring, moved forward thru the water. As one end was fixed, it was compelled to rotate about the motor shaft. The smoke ring, or liquid vortex ring, being entirely free, moves forward at right angles to its plane. The second point is one which may have a bearing on the structure of the hydrogen flocculi surrounding bipolar sun-spots. You will notice that the appearance of the vortex ring is not precisely the same in this side view of its upper and lower faces. Above we see a hood or arch, which is absent below, where the stream lines are straight and axial opposite the center of the ring, and become more and more convex on either side of this axis. We will return to this presently.

Our hypothesis suggests, then, that a typical bipolar sun-spot is like half of one of these vortex rings. If so, it should exhibit the motion of a vortex ring, and move at right angles to the line joining the spots. As this line usually lies nearly east and west on the Sun, a bipolar spot should move to the north or south, its direction of motion being determined by that of the inner edge of the ring.

Hence we must know the law of rotation of sun-spot vortices, which is indicated by the figure, if recent observations may be trusted. According to this, low latitude spots should move toward the equator, while high latitude spots should move toward the poles. Both CARRINGTON and DYSON found small average motions in these directions for low and high latitude spots, but it remains to be seen whether a rediscussion of the the material, eliminating single spots and averaging for the correct zones of latitude would correspond equally well. Then would come the question of the spot velocities, which now appear to be too low. But without dwelling on these points, which require additional solar and laboratory work, we may turn to the last illustrations I shall present.

In the solar atmosphere near sun-spots, as I have already remarked, there are extensive vortex phenomena, which can be photographed with the red line ($H\alpha$) of hydrogen. Some have regarded these as hydro-dynamic vortices, but others have considered them to represent the paths of electrically charged particles as defined by the magnetic fields in sun-spots. Another simple experiment may help us to see what hydro-dynamic influence a low-lying sun-spot vortex, single or double, would have on the solar atmosphere above it.

Let the water in this tank represent the solar photosphere. Just below the surface, and extending nearly up to it, is a small paddle wheel, with vertical axis, which may be set into rotation by an electric motor. The circulation in the liquid vortex thus produced is similar to that in a sun-spot; upward and spirally outward along the surface. Let us now stop the paddle and fill this enclosed space above the water with smoke. When the paddle is once more set into rotation a secondary vortex is produced in the smoke, which is drawn outward on the water from the center of our artificial spot. The smoke at higher levels, flowing inward and downward to replace the smoke thrown outward below, moves along spiral stream-lines, plainly visible when sunlight is sent into the tank from one side. If we photograph these, as Mr. LUCKEY has done, and compare them with the stream-lines of the hydrogen flocculi surrounding sun-spots, we find some distinct points of resemblance, both for single and double spots.

Take, for example, the flocculi surrounding this bipolar spot group, as photographed by Fox with the Rumford spectroheliograph. Note the lack of symmetry on opposite sides of the axis, both in the flocculi and the smoke. Note also the resemblance to a moving liquid vortex, seen from a point in the plane of its ring. In all these cases the direction of rotation of spot, paddle, or ring is the same: clockwise on the right and counter-clockwise on the left. See how the stream-lines come in at one side nearly at right angles to the axis of the group, exhibit greater and greater curvature to the right and left, and form on the opposite side of the axis a hood or arch.

But we may go further. The spectroheliograph, by a method I will not stop to explain, permits us to photograph the solar atmosphere at many different levels. It is precisely as tho we were able to stand vertically above a tree (which we must assume to be transparent), and photograph sections at various heights thru the trunk and branches. Such pictures of the solar atmosphere about sun-spots show little or no evidence of vortex motion near the photosphere. But after a certain height is attained the stream-lines appear.

It is interesting to compare with these solar results the structure of the smoke vortices at different levels. This can be observed and photographed by illuminating a thin layer of the smoke at any distance above the water by sunlight passing thru a horizontal slit. At high levels the stream-lines are nearly radial, as they appear to be in the Sun. Lower down they are more sharply curved, and their resemblance to the solar flocculi is apparently very close in some cases. Still lower the curvature is more marked than we can detect in the Sun, and we begin to have doubts as to the validity of the comparison. It is true that we finally reach a point, close to the water, where the inflow is suddenly changed to an outflow, and where the vortex structure is not in evidence. But the resulting appearance can hardly be said to be reflected in the structure of the low-lying calcium flocculi, and more study of this region is certainly needed. It must be remembered that the sudden change of density at the water level does not correspond with the gradual change of pressure in the solar atmosphere. The photosphere, instead of being a liquid, is a mass of metallic vapors, at a temperature above 6000° C, possibly containing small liquid particles in suspension. The pressure increases from vacuum tube values at high levels in the chromosphere to about one atmosphere near the photosphere. Thus it is evident that our experiments should be modified to conform more nearly to solar conditions before any conclusions can be based upon them.

A final experiment with our smoke vortices will show how we may imitate, at least superficially, the appearance of solar prominences near sun-spots. Here are some remarkable photographs by SLOCUM, showing a solar prominence in the act of being drawn into a spot. If we illuminate a vertical cross-section of our vortex with a beam of sunlight, we can see the smoke being drawn toward the artificial sun-spot in the water below it. Near the water level it turns sharply and moves outward again, an effect not seen in the Sun, unless it is partially indicated by the spectroscopic observations of EVERSHED and ST. JOHN.

In reviewing the evidence afforded by these experiments we clearly recognize that we have passed rapidly from the firm ground of demonstration, afforded by the existence of the ZEEMAN effect in sun-spots, to the doubtful region of conjecture, where we must be constantly on our guard against specious resemblances. The manner in which a flexible columnar vortex transforms itself into a semi-circular vortex ring is certainly suggestive, but this does not justify the conclusion that the same thing actually happens in bipolar sun-spots. As a matter of fact, when we examine complex spot groups showing, it is true, opposite magnetic fields at their emities, but containing innumerable small spots distributed along the axis of the group, we find it hard to believe that they represent a semi-circular vortex ring. Again, if we find in the hydrogen flocculi a nearly symmetrical structure resembling the lines of force between opposite magnetic poles, we may be led toward the view that electromagnetic, rather than hydrodynamic forces, are dominant. Such things teach us to realize that our experiments are imperfect, and should be brought more closely into harmony with solar conditions. But while exercising every precaution we need never fear to guide our successive steps by hypotheses, so long as we maintain an open mind, and adhere to that admirable definition of Sir JOSEPH THOMSON: "An hypothesis is a policy and not a creed."

NOTE ON THE ATMOSPHERIC CONDITIONS REQUIRED FOR ASTRONOMICAL OBSERVATIONS.

By John Evershed.

In an interesting article on this subject in the *Publications* of the Astronomical Society of the Pacific, No. 158, April, 1915, Dr. Campbell very kindly refers to my observations in Kashmir, giving an abstract of the Kodaikanal Bulletin, No. 42, in which I contrast the conditions on the valley-floor of Kashmir with those on the mountain-top at Kodaikanal. In this bulletin I showed that, owing to the absence of convection currents which are so ruinous to good definition, the conditions for solar observation are very greatly superior in the valley compared with the mountain-top. Dr. Campbell, however, asks for information as to the night conditions on the mountain-top.

I am very glad of this opportunity to discuss the climate of Kodaikanal, because I consider that my experiences point to the urgent necessity of further research in order to discover the best possible sites for future observatories, and the results of my observations make me very hopeful that vastly better conditions are actually available than those which have hitherto been considered the best.

At Kodaikanal very little night observation is done, but such work as the photography of comets and their spectra, or occasional observation of planetary markings, has left a distinctly unfavorable impression. The climate is a moist one, with a mean annual rainfall of about 60 inches. Roughly speaking, there is a dry and a wet season, that is to say, dry spells of weather may be expected during the months January to April inclusive, whilst fine mornings are prevalent also in December and May. The remaining six months, June-November, are dominated by monsoon conditions, and are usually wet, cloudy, and windy, with occasional breaks of finer weather. When the monsoon is of normal intensity, observing conditions day or night are hopelessly bad. One may, nevertheless, obtain almost daily photographs of the Sun during this season, if a continuous watch is kept and advantage taken of the least opening in the pall of cloud; but such photographs are of no great value, owing to poor definition. There is usually some amelioration of these conditions in the month of September, when the general direction of the monsoon winds is changing from southwest to northeast.

In the dry season, and during spells of clear dry weather, the night definition is generally very good as observed with a 6-inch telescope. I do not remember, however, to have ever seen such perfect definition as Prof. W. H. PICKERING describes at his station in Jamaica. I believe that, with high power, star-images generally show some slight fluctuations, but critical tests with large telescopes have not been made.

For ordinary photography of comets, etc., the dry spells are almost ideal for transparency, and during such times the sky in the daytime is of a deep blue color right up to the Sun's limb and down to the horizon. Unfortunately we do not get more than two or three such spells during a dry season, each perhaps lasting a week or ten days.

The less favorable weather during the dry season is characterized by the prevalence of thin streaky cloud at a high elevation. This has a strong tendency to form immediately over the mountain mass, the sky over the adjacent plains being often quite clear. This diffusive sky is a great hindrance to all spectrographic work, day or night. There is also much condensation of cumulus cloud during the mornings, and this frequently develops in the afternoon, producing thunderstorms and heavy rain. If it clears at nightfall, observations are greatly interfered with by moisture and by thin clouds condensing and re-evaporating in the most exasperating way, often precisely at the position of some comet or other interesting object one is attempting to observe.[1]

It appears to me that the periodical long-continued atmospheric disturbances due to the monsoon currents are the bane of tropical stations; at any rate this is emphatically the case in these longitudes, and far drier and calmer conditions would certainly be found in higher latitudes, as for instance in the two desert belts of the Earth between parallels of 20° and 30° north and south. I do not, however, recommend a location in actual desert regions, where many obvious disadvantages would outweigh the advantage of clear skies; but I consider the ideal locality would be on an oceanic island situated in one of these belts, and for solar work the smaller the island and the greater the extent of the surrounding ocean the better. Everyone who has traveled much by sea will call to mind the remarkable uniformity in the temperature conditions over the ocean. The diurnal range of temperature is much smaller than on land, and in calm weather there is nothing to produce sharp contrasts of temperature. The Sun has very little heating effect on the sea, the energy of the solar rays being absorbed in producing evaporation. The result must be that the normal temperature gradient in the air over the sea is far more uniform than over the land, where strongly heated surfaces produce violent convection currents, more especially in broken mountainous country.

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[1] In going over our records, I find that of seven bright comets which have appeared in the period 1907-1911 inclusive two only appeared in the dry season, and of these Halley's comet is the only one which could be photographed under really good conditions, during April and the early part of May, 1910.

The remarkable experience I have had of excellent solar definition near to the sea in New Zealand and Southwest Australia, and also I may add on a small island a few yards across in the middle of an extensive lake in the Kashmir Valley, tends to confirm the conclusion that an extensive water surface should be favorable to good definition, and I am now able to supplement these observations by reports of the solar definition carried out during several months by Mr. GIBBS, of Nelson, New Zealand, at the coast station selected by me for the Cawthron Observatory. Mr. GIBBS reports that during the typical winter weather with very light sea-breezes during the day the definition on a scale of 5 ranges between 4, 4½, and 5, practically from dawn to dark. Such a state of things is absolutely undreamed of at hill stations, and Mr. CAWTHRON is greatly to be congratulated on the splendid opportunity for utilizing such conditions. Mr. GIBBS further states that when the wind is strong and from the southwest, or still worse from the southeast, definition is bad. These winds at Nelson are off the land. It appears clear, therefore, that when the wind is d off the sea it brings in the remarkably uniform empe ure conditions which must obtain over the ocean. Probably the great contrast of temperature conditions over the sea and over the land would cause extensive atmospheric disturbances and poor definition at continental coast stations; on islands, however, such disturbances would be insignificant, and the conditions would approximate to the uniformity over oceans.

That the latitude of the island has not much effect on this question of definition appears to be indicated by a report I have just received from Rev. A. L. CORTIE, S. J., who observed the total eclipse of the Sun of August 21, 1914, from the small island of Hernosand on the Baltic. He writes that with a southeast wind, *i. e.* a wind blowing across 150 or 200 miles of sea, "the solar definition is practically perfect."

After these experiences it is not at all surprising to read that at Mandeville in Jamaica "the Moon is as clearly seen as if our atmosphere were entirely removed," while "it is doubtful whether any portion of the civilized world can furnish poorer seeing than is usually found in our Eastern States." Is it not worth considering whether this good definition may be due to the uniformity of temperature gradients over the sea in the neighborhood of Jamaica, and that the bad definition found in the Eastern States of America is due to violent atmospheric convection set up by irregular heating of the ground over mountains and plains, and to the contrast of conditions over the continental land-mass and the adjacent Atlantic Ocean?

It appears to me probable that over an enormously extended land-mass uniformity of temperature gradients can scarcely ever be realized, whereas over extended oceans, where the solar rays have so little heating effect, and there are no irregularities of surface, uniformity would be the rule. I consider that it would be well worth while to organize a visit to some of the Pacific Islands, with the special object of observing the definition both day and night. The innumerable islands both north and south of the equator in this ocean afford ample opportunity for selecting a site in a latitude where clear skies are prevalent. I shall never cease to regret having had no telescope to take ashore when I visited Hawaii in 1906. I shall certainly take the first opportunity that occurs to test the solar definition on a small oceanic island.

KODAIKANAL, June 15, 1915.

AN ERROR IN RADIAL VELOCITY OBSERVATIONS ARISING FROM NON-UNIFORM SLIT ILLUMINATION.

By REYNOLD K. YOUNG.

It has been a common experience with radial velocity observers to obtain spectrograms giving unaccountably large residuals. For a three prism instrument the probable error of measurement as determined from the agreement of the lines is certainly less than one-half a kilometer and often as small as one or two-tenths, while the mean result may be in error by as much as three kilometers. For a one-prism instrument the probable error of measurement of a late type star is less than one kilometer, yet plates have been found which give velocities as much as ten kilometers from the truth.

These large errors have been ascribed sometimes to changes within the star, sometimes to flexure or temperature effects of the spectrograph and sometimes to the guiding or non-uniform illumination of the slit. Some results obtained here recently from plates taken with a one-prism spectrograph seem to indicate that the major portion of such errors may be ascribed to the latter cause.

On June 1st two plates were taken of *α Boötis*. For the first, the image was held on the south edge of the slit and for the second on the north edge. This procedure was followed purposely to ascertain if it were possible to produce different velocities by the method of guiding. Both plates are weak in the violet but there is no doubt that there is a relative displacement indicated by the two plates coresponding to a velocity of about twenty-five kilometers. A few days later the experiment was repeated, save that three plates were secured: the first with the slit north of the star, the second guided normally and the third with the slit south of the star. These plates confirm the previous result. The first plate gives a velocity about thirteen kilometers more positive than the second, and the third a result about thirteen kilometers more negative. Of the three plates, the first is weak in the violet, but the second and third appear to be perfectly normal plates.

In the June number of this journal, Dr. W. W. CAMPBELL gives results from observations of *Venus* which seem to show that the same effect may be present when guiding on the terminator of a planet's image.

DOMINION OBSERVATORY, July 3, 1915.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1915.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter. Sept.	1, $6^h 57^m$ A.M.	Last Quarter..Oct.	1, $1^h 44^m$ A.M.
New Moon .. "	9, 2 53 A.M.	New Moon.... "	8, 1 42 P.M.
First Quarter. "	15, 11 21 P.M.	First Quarter.. "	15, 5 51 A.M.
Full Moon... "	23, 1 35 A.M.	Full Moon.... "	22, 4 15 P.M.
		Last Quarter.. "	30, 8 40 P.M.

The autumnal equinox, the time when the Sun crosses the equator from north to south, occurs September 23d shortly after 7 P. M.

Mercury passed superior conjunction with the Sun on August 14th, and is an evening star until it reaches inferior conjunction on October 22d. It reaches the greatest east elongation on the evening of September 27th. The apparent distance of the planet from the Sun at this time, 26° 2′, is rather larger than the usual greatest elongation distance; but the planet will not remain above the horizon as much as an hour after sunset thruout the two months period, and it is therefore not in good position for naked-eye view. This is what usually happens during the east elongations which come in the autumn. The planet moves along in a path, roughly speaking, the same as that of the Sun among the stars, and at the time of greatest east elongation will be at a point which the Sun will reach about a month later, except that on account of its being in the southern half of its orbit it will be 2° south of the normal Sun position. In all, it will on September 27th be more than 12° south of the Sun, and will remain above the horizon only three-fourths of an hour after sunset. After passing inferior conjunction on October 22d it becomes a morning star, moves rapidly away from the Sun and at the same time is some distance north of that body. By the end of October it rises nearly ur and a half before sunrise and is an easy object in the mor ng twilight.

Venus passes superior conjunction with the Sun on September 12th and changes from morning to evening star. Thruout September its times of setting and rising are almost coincident with those of the Sun, and it will be out of reach of naked-eye view. By October 16th it has moved far enuf away from the Sun to remain above the horizon nearly half an hour after sunset, and this interval increases about ten minutes by the end of the month. Its great brightness, altho it is nearly at its minimum, will permit naked-eye view low down in the evening twilight in the latter part of the month; but the present two months, September and October, give the poorest opportunity of the year for views of *Venus*.

Mars is swinging around toward a better position for observation. On September 1st it rises about half an hour after midnight, and at the end of October a little more than half an hour before midnight. During the two months it moves about 36° eastward and 3° southward thru the constellations *Gemini* and *Cancer*. During the latter part of September it is in the neighborhood of *Castor* and *Pollux*, α and β *Geminorum*, and on September 25th passes about 6° south of *Pollux*, the southern and eastern one of the pair. On September 10th it passes conjunction with *Saturn* at a distance of 1° 8′ to the north, and on October 11th it passes 1° 28′ north of *Neptune*. Its distance from the Earth diminishes 39 millions of miles and its brightness increases 60 per cent during the two months, so that it is beginning to be quite a conspicuous object, altho only about one-fourth as bright as it will be when it comes to opposition in February next.

This is the best time of the year for seeing *Jupiter*, as it is above the horizon most of the night. It comes to opposition with the Sun on September 17th. On September 1st it rises a little more than an hour after sunset, on October 1st about an hour before sunset and at the end of October it remains above the horizon until about 2:30 A. M. It moves about 6° westward and 2° southward in the constellation *Pisces*.

Saturn on September 1st rises at about 1 A. M. and at the end of October shortly after 9 P. M. It is in the constellation

Gemini, south and west of *Castor* and *Pollux* and moves about 3° eastward during the month. The motion gradually diminishes until October 29th, when the planet becomes stationary and then begins its retrograde or westward motion. At that date it is 7° west and the same amount south of *Pollux*, the southern and eastern of the two stars. As seen in the telescope the rings are not quite as wide open as they were during the early part of the year, the minor axis being about 40 per cent of the major.

Uranus is in fairly good position for evening observation. It is well above the horizon at sunset and passes the meridian shortly after 10 P. M. on September 1st and shortly after 6 P. M. on October 31st. It is in the constellation *Capricorn* and its motion is slowly westward until October 22d, when it becomes stationary and then resumes its eastward course. No bright star is near it, but a fourth magnitude star, *θ Capricorni*, is quite close during early September. The planet will pass about 8′, one-quarter of the Moon's apparent diameter, south of the star on September 4th. It then moves away to the west of the star, but after the planet resumes its eastward motion it will pass the star again on December 27th.

Neptune remains in the constellation *Cancer*, too faint for naked-eye view.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1915.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon...	Nov. 6,	11^h	52^m	P.M.	New Moon...	Dec. 6,	10^h	4^m	P.M.
First Quarter	" 13,	3	3	P.M.	First Quarter	" 13,	3	38	A.M.
Full Moon...	" 21,	9	36	A.M.	Full Moon...	" 21,	4	52	A.M.
Last Quarter.	" 29,	2	15	P.M.	Last Quarter.	" 29,	4	59	A.M.

The Sun reaches its most southerly point and winter begins December 22d about 3 P. M., Pacific Time.

Mercury is a morning star, having passed inferior conjunction on October 22d, and will remain a morning star until it comes to superior conjunction on December 15th. At first its motion away from the Sun is quite rapid, so that by November 1st it rises nearly an hour and a half before sunrise. For a few days before this date it may be seen in the early morning twilight. It reaches greatest west elongation on November 7th. Its apparent distance from the Sun is then 18° 57′, rather a small distance for a greatest elongation, but the planet passed its aphelion only a week before, on October 30th. The interval of an hour and a half between the rising of the planet and sunrise continues until about the middle of the month, and does not become as small as an hour until near the close of the month. After passing superior conjunction it becomes an evening star, but does not reach a great enuf distance for naked-eye observations until after the end of December.

Venus is an evening star, having passed superior conjunction with the Sun on September 12th. But as it has moved away from the Sun rather slowly and is some distance south of the Sun until well into December, it has not been long above the horizon after sunset. On November 1st the interval is less than forty minutes and does not become as much as an hour until after the middle of the month. After December 1st the interval increases much more rapidly, so that it is about two hours on December 31st. It is in aphelion on December 9th, but this makes little difference in the relative positions of planet and Sun on account of the almost perfect circularity of the orbit of *Venus*.

Mars is gradually approaching opposition, but will not reach it until February 9, 1916. On November 1st it rises shortly after 11 P. M. and on December 31st shortly before 9 P. M. It moves 17° eastward and 4° southward from the extreme eastward part of *Cancer* into *Leo*, with a gradually diminishing motion until, on the last day of December, it changes its position by about one minute of arc, an amount far too small for naked-eye observation, and is nearly ready to begin its retrograde or westward motion. Thruout December it will not be far from the first magnitude star *Regulus, α Leonis*. On December 13th the planet and star are in conjunction, the former being about 2° 30′ north of the latter, and also about the same distance south of the fourth magnitude star *α Leonis,* the star which marks the junction of the handle and blade of the sickle, while *Regulus* marks the end of the handle. After this conjunction *Mars* moves about 2° to the east by the end of the month. Soon after the beginning of the year 1916 the planet will begin its retrograde motion and there will be another conjunction with *Regulus*. The motion of the planet with respect to the star thruout December and January will give a beginner in astronomy an unusually good opportunity for study of the direct and retrograde motion of a planet. *Mars* is still nearing the Earth quite rapidly, the distance diminishing from 123 to 77 millions of miles during the two months. On December 8th its distance from us is equal to the Earth's mean distance from the Sun. Its brightness also will increase by about one-third. At the end of the year it will be more than six times as bright as it was at the beginning, and it will not gain very much more before its maximum, near the time of opposition.

Jupiter is in fine position for evening observation. On November 1st it is on the meridian shortly before 9 P. M. and at the end of December shortly after sunset. It is in the constellation *Pisces* and up to the middle of the month moves westward slowly and with diminishing rapidity, the whole motion being less than 20′. It finishes this "arc of retrogression" on November 14th, and is then in nearly exactly the same place among the stars as it was on April 26th, the distance traveled during the backward motion being about 6° and the time occupied a little less than four months. After passing the stationary point the planet will move a little more than 3° eastward.

Saturn is getting into good position for evening observation as it approaches opposition. It rises shortly after 9 P. M. on November 1st, and at about 5 P. M. on December 31st. It retrogrades, moves westward, nearly 6°, during the two months in the constellation *Gemini*, south and west of *Castor* and *Pollux*.

Uranus is in the southwestern sky in the evening. It moves about 2° eastward in the constellation *Capricorn*. On December 7th it is again in conjunction with the fourth magnitude *apricorni,* passing about 6° to the south of the star. By the end of December it sets at about 7:30, but on account of its faintness it cannot be seen except when it it a considerable distance above the horizon.

Neptune is still in the constellation Cancer, too faint for naked-eye observation.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Appointment of Martin Kellogg Fellow.

Mr. Roscoe F. Sanford (A. B., University of Minnesota, 1905), has been appointed Martin Kellogg Fellow for the year 1915-1916. Mr. Sanford was in residence at the Lick Observatory, as Assistant, for two years (1906-1908), resigning to accept a position as assistant in the expedition to San Luis, Argentina, under the Carnegie Institution. After a service of three years, he went to Santiago, Chile, where he held the position of Assistant, and, later, of Assistant Astronomer in the D. O. Mills Expedition from the Lick Observatory. Mr. Sanford will spend the year at Mount Hamilton.

A New Bright Double Star.

The star 41 *Ophiuchi* (R. A. 1900 $=17^h\ 11^m\ 29^s$; Decl. $=-0°\ 20'$), was noted as "possibly a close unequal pair" in 1905. The suspicion could not be verified at the time and the star was not examined again until July 1, 1915. Probably the angular distance between the components had increased in the interval, for the companion was then easily seen. Measures on three nights give the position, 1915.54, 298°.3, 0″. 52.

The magnitude in *H. A.* 50 is 4.82, the spectral class G 5. I estimate the companion to be fully three magnitudes fainter than its primary. From the data in Boss's Preliminary General Catalogue, I find the proper motion of the primary to be 0″.065 in 204°.6. This is undoubtedly shared by the companion and it is safe to say that the two stars constitute a physical system.

R. G. Aitken.

August 10, 1915.

NOTE ON THE RADIAL VELOCITY OF THE NEBULA 1068.

A spectrogram of the spiral nebula N. G. C. 1068 was obtained at Mount Hamilton on December 31, 1914, with a spectrograph of one-prism dispersion and a camera of short focal length.

The positions of the three bright lines $H\beta$, N_1 and N_2 were measured by Messrs. GREEN and MOORE. Interpreting the displacements of these lines on the Doppler-Fizeau principle, the radial velocity of the nebula with reference to the Sun is $+910^{km}$ per second.

It is of interest to note that this is about the mean of the values published by Mr. SLIPHER, $+1100^{km}$, and by Mr. PEASE, $+765^{km}$.

J. H. MOORE.

GENERAL NOTES.

THE FIRST PACIFIC COAST MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, AUGUST 2-7, 1915.

This first Pacific Coast meeting proved to be one of the most interesting and profitable in the history of the Association and of the affiliated societies which make up the sections of the Association. The thanks of all are due to the very efficient Pacific Coast Committee for the perfection of its arrangements for the meetings, social functions, and excursions of the individual sections, and in particular for the excellent printed general program, which so completely anticipated every need for information on the part of the visiting scientists. With meetings held at San Francisco, Berkeley, and Stanford, some confusion might have been expected, but, thanks mainly to the complete information given in the official program, none was experienced.

In reporting these meetings for the readers of the *Publications* it is our intention to mention briefly some of the more general features of the conference, and to give in more detail the meetings of the American Astronomical Society.

The meetings were inaugurated by a joint session of the Association and affiliated societies at the Scottish Rite Auditorium on Monday morning, where Dr. W. W. CAMPBELL, President of the Association, very happily introduced for brief speeches of welcome to the visiting scientists, Mr. WM. H. CROCKER, Dr. B. I. WHEELER, Dr. D. S. JORDAN, Dr. H. F. OSBORN, and Dr. L. O. HOWARD. Following these Dr. CAMPBELL gave his presidential address on the subject, "Science and Civilization." This able address held the interest and attention of the large audience, and we regret that lack of space prevents giving an abstract of it here; it will be published in full in *Science*.

No sessions were held on Monday afternoon, but a very enjoyable general reception was given that evening at the California Building on the Exposition grounds.

The rest of the week was given up to the meetings of the various sections of the Association at Berkeley and at Stanford. On Wednesday over four hundred members and friends were taken to Stanford on a special train. After a general meeting in the Assembly Hall of the University, at which Chancellor Jordan made a short address of welcome, responded to by Dr. Campbell, luncheon was served in the Memorial Court of the quadrangle. Opportunity was given to inspect the buildings and grounds, and sessions of the various societies were held during the afternoon.

No sessions of the sections were held in the evenings but addresses before the Association as a whole were given in the Scottish Rite Auditorium, San Francisco, on Tuesday, Thursday and Friday evenings. The speakers and subjects, in order, were: Professor R. A. Daly, Harvard University, *Problems of the Pacific Islands;* Professor W. B. Scott, Princeton University, *The Isthmus of Panama and its Influence on the Animal Life of North and South America;* Dr. P. S. Reinsch, American Ambassador to China, *The Economic Future of the Pacific.*

Wednesday evening was set aside for the annual dinners and reunions of the various societies.

The meetings of the American Astronomical Society were well attended, and only the fact that quite a proportion of the papers were perforce read by title made it possible to get thru the very full list of papers presented. Among those present at the sessions were:—

Abbot, C. E. Adams, Aitken, Alter, Apple, Ash, Babcock, Bauer, Brackett, Brasch, Burckhalter, W. W. Campbell, Cebrian, Costa, Crawford, Curtis, Cushing, C. L. Doolittle, Douglass, Edwards, Eichelberger, Einarsson, Fath, Gray, G. E. Hale, W. H. Hale, Hamilton, Hedrick, Joy, A. S. King, Klotz, Larkin, Lee, Leuschner, Martens, Meggers, Meyer, Mitchell, Molera, Moore, Morse, Motherwell, Nicholson, Paddock, Plaskett, Richardson, Rigge, Schlesinger, Seares, Segla, Shapley, Stebbins, St. John, Swezey, Townley, Truman, Tucker, Turner, Vrooman, Wright, Ziel, and the Misses Furness, Harwood, Hobe, Lamson, O'Halloran, Schumacher, Schwartz, and Ware.

On Tuesday morning a joint session of Sections A and B of the Association, the American Astronomical Society, the American Mathematical Society, and the American Physical Society was held at Berkeley, Professor Leuschner, Vice-president of Section A, presiding. The addresses on this occasion were two in number: "The Human Significance of Mathematics," by Professor C. J. Keyser, of Columbia University, and "The Work of a Modern Observatory," by Director G. E. Hale. It is impossible to give an abstract of Professor Keyser's powerful and deeply philosophical address, and it is to be hoped that this will soon be published in full. Were it possible to summarize this theme in a few sentences, it might perhaps be said that the title might well have been, "The Ethical Significance of Mathematics," for the speaker did not touch at all upon the more material points of contact which mathematics has with modern life and civilization, but rather upon the importance which this great body of science has for the souls of men; from an ethical and philosophical standpoint, the existence of this great realm of pure thought, of absolute truth, of undeviating law, is of incalculable value.

Director Hale's very interesting address is published elsewhere in this number; it was profusely illustrated with lantern slides and by a number of experiments illustrating the theories of sun-spots.

After a pleasant luncheon at the Faculty Club, where the astronomers, physicists, and mathematicians were the guests of Professors Haskell, Leuschner, and Lewis, the Astronomical Society met in joint session with the Astronomical Society of the Pacific in the Student's Observatory. At this session the Bruce Gold Medal of the Astronomical Society of the Pacific was presented to Dr. Campbell. The very happy address of presentation was made by Dr. Crawford, and is printed in this number of the *Publications*.

The following papers were presented at the various sessions of the Society:—

1. Frank Schlesinger: Description of the Thaw Refractor of the Allegheny Observatory.

2. W. W. Campbell and J. H. Moore, Lick Observatory: On the Radial Velocities of the Planetary and Irregular Nebulæ.

3. S. D. Townley, Stanford University: The Designation of Variable Stars.

4. S. D. Townley: The Variable 6, 1914.

5. R. G. Aitken, Lick Observatory: A Statistical Study of Double Stars in the Northern Sky.

6. Jacob Kunz and Joel Stebbins, University of Illinois: Progress with the Photo-Electric Photometer.

7. H. D. Curtis, Lick Observatory: Nebular Proper Motions.

8. A. H. Joy, Yerkes Observatory, (introduced by O. J. Lee): Investigation of the Cluster M 37 for Proper Motion from Plates taken with the 40-inch Refractor of the Yerkes Observatory.

9. W. H. Wright, Lick Observatory: The Spectra of the Gaseous Nebulæ, and Some Points of Corespondence between Them and Other Celestial Spectra.

10. E. E. Barnard, Yerkes Observatory: Photographic Comparison of a Bright Nebula with a Dark One, and the Possible Luminosity of Space.

11. Margaret Harwood: The Light Curve of *Eros* in 1914.

12. W. S. Adams, Mount Wilson Solar Observatory: The Radial Velocities of the More Distant Stars.

13. Elliott Smith, Cincinnati Observatory: The Evolution of a Gravitating, Rotating, Condensing Fluid.

14. S. A. Mitchell, McCormick Observatory: Parallax Work at the McCormick Observatory.

15. S. A. Mitchell: Request for Meteor Observations.

16. O. J. Lee and A. H. Joy, Yerkes Observatory: Stellar Parallaxes derived from Plates taken with the 40-inch Refractor of the Yerkes Observatory.

17. O. J. Lee, Yerkes Observatory: Preliminary Report on General Stellar Parallaxes in Zone + 45° of the Selected Areas.

18. A. VAN MAANEN, Mt. Wilson Solar Observatory: The Determination of Stellar Parallaxes with the 60-inch Reflector at Mt. Wilson.

19. FRANK D. URIE, Elgin Observatory: Chronographic Registration of the Arlington Radio Time Signals.

20. FRANK D. URIE: Chronographic Determination of the Lag Between the Arlington and Key West Radio Time Signals.

21. R. H. TUCKER, Lick Observatory: The Places of the A. G. Zone Catalogs.

22. FRANK W. VERY, Westwood Observatory: Fundamental Distinctions Special to the Process of Transmission of Terrestrial Radiation by the Atmosphere, and the Value which is Obtained for the Coefficient of Transmission when these are Considered.

23. FRANK W. VERY: Spectrum of the Earthshine.

24. L. A. BAUER, Carnegie Institution: General Results of the Magnetic Survey of the Pacific Ocean by the Carnegie Institution of Washington.

25. C. G. ABBOT, Smithsonian Institution: The Variability of the Sun.

26. D. P. TODD, Amherst Observatory: Photographing the Corona of August 21, 1914, in Russia.

27. F. W. RIGGE, Creighton University: The Solar Eclipse of 1916, December 24th-25th.

28. A. E. DOUGLASS, University of Arizona: Correlation between Sun-spots, Weather, and Tree Growth.

29. A. E. DOUGLASS: Photographs of the Zodiacal Light and Gegenschein.

30. C. E. ST. JOHN, W. S. ADAMS, and Miss LOUISE WARE, Mt. Wilson: Recent Observations of the Rotation of the Sun.

31. MIGUEL SELGA, Manila Observatory: The Orbit of the Spectroscopic Binary Sigma *Scorpii*.

32. F. H. SEARES, Mt. Wilson: Photographic Magnitudes of Stars in the Selected Areas.

33. HARLOW SHAPLEY, Mt. Wilson: Magnitudes and Colors of Stars in the *Hercules* Cluster.

34. F. C. JORDAN, Allegheny Observatory: Photographic Photometry with the 30-inch Thaw Refractor.

35. D. Alter, University of California: The Orbit of *Æthra.*

36. Annie J. Cannon, Harvard Observatory: The New Draper Catalog.

37. C. E. Adams, Lick Observatory: Preliminary Note on the Determination of the Moon's Place by Photography.

38. W. C. Rufus: The Spectra of Stars belonging to Class R.

39. H. S. Leavitt, Harvard Observatory: A Star having a Large Color Index.

40. G. F. Paddock, Lick Observatory: Formulæ for Spectroscopic Binary Orbits of Small Eccentricity and for Systems showing Two Spectra.

41. G. F. Paddock: The Spectroscopic Binary v_4 *Eridani.*

42. A. F. Beal, Allegheny Observatory: Note on η *Orionis.*

43. Z. Daniel: Note on VV *Orionis.*

44. C. D. Perrine, Córdoba Observatory: An Apparent Relation between the Inherent Velocities of the Brighter Stars and Their Magnitudes.

45. C. D. Perrine: Some Peculiarities of an Apparently Semi-systematic Nature in the Radial Velocities of the Brighter Stars of different Spectral Classes, and Their Effect upon the Solar Motion.

46. S. B. Nicholson, University of California: The Ninth Satellite of *Jupiter.*

47. R. K. Young, Dominion Observatory: The Mean Distance of the Stars Whose Radial Velocities, Proper Motions, and Parallaxes have been Determined.

Many of these papers were illustrated by lantern slides; others by charts and diagrams. Abstracts will be printed later in *Popular Astronomy* in the report of the Secretary of the meeting, and most of the papers will be published in full in various technical journals.

The banquet of the astronomers and mathematicians forming Section A of the Association was held on Wednesday evening at the Hotel Oakland, with fifty-one present, and was a most enjoyable occasion.

Some fifty members of the same section visited Mt. Hamilton on Friday, August 6th. During the afternoon a business meeting of the Astronomical Society was held, at which the announcement was made that Professor KAPTEYN was elected an Honorary Member by the Council. Reports of committees were received and officers were balloted for and elected as follows:—

President, E. C. PICKERING.
First Vice-President, W. W. CAMPBELL.
Second Vice-President, F. SCHLESINGER.
Secretary, PHILIP FOX.
Treasurer, Miss ANNIE J. CANNON.
Councillors, E. B. FROST, J. STEBBINS.

At five o'clock the visitors proceeded to the "camp ground" near East Peak, where tables had been set up under the fine oaks at this spot, and partook of a buffet supper with the families of the Lick Observatory staff. In the evening a number of objects were observed with the 36-inch, while at the 12-inch telescope Dr. STEBBINS demonstrated the use of the photo-electric cell. The visitors left for San Jose about ten P. M. The next morning a trip was made to Pleasanton, where Mrs. HEARST had invited the members of the astronomical and mathematical sections to be her guests at her country place, the Hacienda del Pozo de Verona. The recollection of this beautiful spot will doubtless remain with all long after all other incidents of the convocation week are forgotten.

It gives us particular pleasure to record that the Northwestern University, Evanston, Illinois, at commencement, June 9, 1915, conferred upon SHERBURNE WESLEY BURNHAM the degree of Doctor of Science. In making this announcement, Professor BURNHAM was characterized as—

"An astronomer of international renown, an investigator who, starting as an amateur with an instrument of small power, has given distinction to the two greatest telescopes in the world; a discoverer who has made us acquainted with more than a thousand new double-suns; a signal example of devotion to science unswerved by any distraction; a lover of truth; a generous friend whose achievements we are glad to recognize and whose distinction we cannot augment."

We regret to record the death, on May 14, 1915, of Professor Dr. **Oswald Lohse**, chief astronomer at the Royal Astrophysical Observatory at Potsdam, Germany. Born in 1845, Dr. **Lohse** became Professor H. C. **Vogel**'s assistant at the observatory at Bothkamp in 1870, and when the latter, four years later, accepted the directorship of the observatory then being built at Potsdam, he chose **Lohse** as his first assistant. His principal researches relate to surface details and physical peculiarities of the planets *Mars* and *Jupiter*, but he did useful work in observing double stars and computing double-star orbits, and in spectroscopy.

It is reported that the position left vacant by his death has been filled by Professor Dr. **Hans Ludendorf**.

ASSOCIATED OBSERVERS OF MARS.

Dear Sir:—

During the period of the past opposition of *Mars* the writer issued a series of reports on the planet, which were published in *Popular Astronomy*. Nine numbers have so far appeared, and others are in process of preparation. During part of the time, when the changes taking place upon the surface were most readily seen, the reports appeared at intervals of a month, the plan being to issue a regular monthly record or news sheet of the happenings upon the planet. These changes were partly meteorological and partly related to the growth of vegetation, as indicated by the changes in the appearance of the maria and the canals. A system of co-operation by correspondence was established with other observers in different parts of the world, which resulted, it is believed, in mutual advantage. It is now proposed to extend this system so as to include a still larger number of observers.

The particular object in mind depends on the fact that the period of rotation of *Mars*, is about forty minutes longer than that of the Earth, and consequently any single observer can only study a given region of the planet for a few days at a time. Other regions then come into view, and the first region is not again seen by him for about four weeks. Much of interest may happen in that region in the meantime, and interesting changes may take place which will thus be entirely lost to him.

Since most of the observers of *Mars* at present reside between longitudes 15° E. and 115° W., many valuable facts regarding the planet may pass unrecorded, and be permanently lost to science. To overcome this difficulty it is necessary to secure observations as far as may be in all longitudes around our globe. This idea has been very clearly expressed by M. JARRY-DESLOGES in his "Observations des Surfaces Planetaires," **2,** 184.

It is proposed to issue the reports free, to all taking an active part in the observations. They will be forwarded regularly after the receipt by the writer of the first observations and drawings. In Report No. 9 herewith transmitted, suggestions are made as to the regions where changes may be expected, and the time when it is thought that they may occur, but much is likely to happen on the planet which cannot be foreseen. Drawings should be made at least once a week, and more frequently if possible, when the planet is nearest us. Micrometer observations are very desirable from those who are properly equipped and able to reduce the corresponding latitudes and longitudes. Excellent results may be obtained with an 8-inch telescope, but even one of 5 inches aperture will give results of value. Opposition occurs February 9, 1916. Diameter of the disk 15″.0. Little of value can be secured before October 1st, diameter 6″.5, but observations made between that date and the middle of January will have exceptional value, because, since it is necessary to observe shortly before sunrise in order to secure them, they will naturally be few in number. Moreover, it is believed that the changes occurring upon the planet will be more marked during that period than later. Drawings made at a lower altitude than 30° are of little use. On account of the distance of the planet, observations made before December 1st, diameter 9″.5, while they may be of much value, will be a little discouraging, owing to the lack of detail. For these reasons observers will not be asked to begin observing regularly before January, but observations of the *Syrtis Major* made on those dates in October, November, and December indicated in Table I of Report No. 9 would be of exceptional interest.

A monthly report including drawings is desired from each observer, but it is not wished to interfere in any way with the sending of reports and drawings from those who are associated with the British Astronomical Association to their Section. Indeed, it is not in most cases expected to publish the drawings, but only to study them, especially those exhibiting change. After these studies have been completed, at the end of the opposition, the drawings will be returned to those who request it. It is recommended that the observer secure a copy of the *Nautical Almanac.*

Suggestions and remarks regarding the observations will at all times be welcomed, and in order to make the research mutually helpful, information regarding any detail as it appeared at other stations on previous dates will be supplied as far as possible on request. For this reason, as well as to aid in the monthly publication of information, it is very desirable that observers should report as regularly as possible every month.

It is suggested that where two or more available observers exist in any locality they should combine their efforts, using the telescope at different times, and thus increasing the number of observations. While they might properly compare their results before transmitting them, each should take especial care not to be unduly influenced by the drawings of the other.

Copies of *Popular Astronomy* containing the early reports may be obtained if desired by application to Professor H. C. WILSON, "Popular Astronomy," Northfield, Minnesota, U.S.A.

Are you able, and do you feel inclined to take part in this investigation?

If not, will you suggest the matter to some one in your vicinity, or associated with you, who would be able to do so.

What telescopic aperture is available for the research, and is it a refractor or a reflector?

Respectfully yours,

W. H. PICKERING.

HARVARD ASTRONOMICAL STATION,
MANDEVILLE, JAMAICA, B. W. I.,
July 1, 1915.

The ASTRONOMISCHE NACHRICHTEN has just entered upon its 201st volume. In the first number of this volume (No. 4801), the present editor, Professor Dr. H. KOBOLD, briefly reviews the long and honorable history of the journal, which, under the editorship successively of SCHUMACHER (the founder), PETERSEN and HANSEN, C. A. F. PETERS, C. F. W. PETERS, KRUEGER, KREUTZ and KOBOLD, has been a powerful factor in the development of modern astronomy. Tho many other strong journals have been established in more recent years and many observatories have adopted the plan of publishing series of Bulletins, the *Astronomische Nachrichten* still holds a high place in astronomical literature and it is to be hoped that a long and useful future lies before it.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE STUDENTS' OBSERVATORY, BERKELEY, CALIFORNIA, ON JUNE 29, 1915, AT 7:30 P. M.

There were present President R. G. AITKEN and Directors CUSHING, BURCKHALTER, COSTA, CORNISH and RICHARDSON.

Mr. ALFRED S. MAYLOR, of Oak Harbor, Washington, and Mr. S. I. ALLARD, of Eureka, California, were elected members of the Society.

A suggestion was made by President AITKEN, representing the Publication Committee, that the next two issues of the *Publications* be consolidated into one issue, to appear about the last of August. This would include the issues generally printed for the months of August and October. Two reasons were given for this suggestion, one being that of economy and the other being the desirability of introducing some special features into the number which will follow and report the proceedings of the various scientific societies which will meet in the vicinity of San Francisco during the month of August. By authorization of the Board, the matter was left to the discretion and judgment of the Publication Committee.

A letter was read from Secretary of State LANSING, stating that the Bruce Medal, awarded during the past year to Dr. W. W. CAMPBELL, had been received from the French Mint thru the hands of the French Ambassador in Washington and that it was en route to California.

The Secretary read a letter from Mr. ALFRED L. BARROWS, Secretary of the Pacific Division of the American Association for the Advancement of Science, calling attention to the fact that two members should be appointed to represent the Astronomical Society of the Pacific upon the Affiliation Committee of the Pacific Division. By authorization of the Board the President appointed Dr. R. T. CRAWFORD of the Student's Observatory, and Dr. SIDNEY D. TOWNLEY of Stanford University, to serve in that capacity.

Adjourned.

D. S. RICHARDSON, *Secretary.*

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC AT THE STUDENTS' OBSERVATORY, BERKELEY, ON THE EVENING OF JUNE 29, 1915.

By courtesy of Professor CHARLES H. RIEBER, Dean of the Summer Sessions of the University of California, this meeting of the Astronomical Society of the Pacific was conducted as a feature of the said Sessions. It was held in the assembly room of the Student's Observatory and drew out a large and attentive audience. President R. G. AITKEN was in the chair. There being no routine business before the Society, the President proceeded to introduce as the lecturer of the evening, Dr. J. H. MOORE, of the Lick Observatory, who spoke upon the subject of "The Nebulæ."

The lecture was beautifully illustrated with lantern slides and greatly appreciated by all those who had the good fortune to be present.

Adjourned.

D. S. RICHARDSON, *Secretary.*

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE STUDENTS' OBSERVATORY, BERKELEY, ON AUGUST 3, 1915, AT 2 P. M.

This was a joint meeting, held in conjunction with the Eighteenth Session of the American Astronomical Society, the latter organization being one of the affiliated societies of the American Association for the Advancement of Science, and holding its sessions this year in California in connection with Exposition activities.

The meeting was called to order by Dr. FRANK SCHLESINGER, Director of the Allegheny Observatory and Second Vice-president of the American Astronomical Society. After a few preliminary announcements by Secretary STEBBINS and Dr. TOWNLEY, relative to other meetings and entertainments arranged for visiting scientists, the chair was turned over to President R. G. AITKEN, of the Astronomical Society of the Pacific.

The first business on hand was the presentation of the Bruce Gold Medal of the Astronomical Society of the Pacific to Dr. W. W. CAMPBELL. This pleasant duty was gracefully performed by Dr. R. T. CRAWFORD, late President of the Society, in an address of appreciation and deep feeling. The occasion was one which had long been pleasurably anticipated by the old colleagues, students and friends of Dr. CAMPBELL and will not be soon forgotten by those who were so fortunate as to be present. This is the first occasion on which the Bruce Medal has been presented personally to the recipient at an open session of the Society. It is the first time that it has gone to a Californian and member of our own Society; and it is the first time that the enthusiasm provoked by the award has busied a little knot of old comrades in keeping the tears out of their eyes. But that is what happened.

Other papers presented and read were the first six given in the list printed on another page of this number of the *Publications.*

At an informal meeting of the Directors of the Society, held during the afternoon, Dr. C. E. ADAMS, Director of the Hector Observatory, Wellington, New Zealand, was elected a member of the Society.

The meeting as a whole was an eventful one in the history of the Society.

D. S. RICHARDSON, *Secretary.*

OFFICERS OF THE SOCIETY

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Mr. S. D. TOWNLEY	*First Vice-President*
Mr. J. COSTA	*Second Vice-President*
Mr. F. V. CORNISH	*Third Vice-President*
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NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. AITKEN, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished free of cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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DESIGNATION OF VARIABLE STARS.

By Sidney D. Townley.

One cannot but wonder at the lack of foresight displayed by the eminent astronomers who suggested and used various systems of designating variable stars. **Argelander**'s system of using the last letters of the alphabet, beginning with *R*, provides for only nine variables in each constellation, and he apparently had no idea, at first, that this number would ever be exceeded. The systems of **Chandler** and of **Pickering** are both based on the coördinates of the star for 1900 and it does not seem to have occurred to either of these astronomers that our successors of the twenty-first and following centuries might not find it either inspiring or convenient to work out designations of new variables for the epoch of 1900. One argument in favor of **Pickering**'s system was that the number designating the variable gives the right ascension of the star to the nearest minute of time and the declination to the nearest degree. What use will these numbers be in the year 11,900 for example?

In order that we may discuss this subject more intelligently I wish to present in some detail, altho as briefly as possible, the various systems which have been proposed. The first variables discovered were bright stars, hence already had designations, and the necessity for a separate nomenclature was not apparent.

The first catalog of variable stars was published by **Pigott** in the *Philosophical Transactions* for 1786. This list contained twelve stars recognized as certainly variable and 38 others suspected of variability. Four of the twelve variables were *Novæ*. No other catalog appeared until 1844, when two were l, one by Smyth and the other by Argelander. There were 18 stars in Argelander's "Täfelchen," as he called it, and eight of these were without special designation.

In Argelander's second catalog, published in 1850 in Humboldt's *Kosmos,* 24 variables were listed and Argelander's now well known nomenclature, *R*, *S*, *T*, etc., was used for the first time. He did not include *Novæ* under the head of variable stars. Argelander's nomenclature was followed by Schönfeld and, with extensions, by most, if not all, other compilers of catalogs in more recent times.

The limitations of the Argelander nomenclature were early recognized, for Chambers wrote as far back as 1865, "The time seems arriving when it will be imperatively necessary to adopt a new nomenclature for variable stars. The present system, besides being inartistic, is gradually, and not very slowly either, drawing to a natural termination; indeed in one constellation—*Virgo*—but two letters remain unappropriated.[1]

At the meeting of the Astronomische Gesellschaft held in Strassburg in 1881, Hartwig proposed using the double letters, *RR*, *RS*, etc. This would give 45 additional symbols, the combinations of nine letters taken two at a time, plus the nine combinations, *RR*, *SS*, etc., or a total of 54 symbols for each constellation. This suggestion was adopted and first used in 1888, both by Chandler in his first catalog of variable stars and also by Schönfeld in the ephemerides for 1889.

The device proved to be sufficient until about 1904, when a further extension became necessary. This time combinations of the first letters of the alphabet, *AA*, *AB*, etc., were employed. Leaving out the letter *J*, we find that this device adds 280 new symbols and these have proved ample up to the present time. The greatest number of variables are found in the constellation *Orion*, 32 of the 280 new symbols having already been used in this constellation.

It is evident, however, that even these symbols may become exhausted in a comparatively short time. What shall we do then? Shall we devise a third extension to the Argelander system or shall we break away from it entirely and adopt a new system? Many suggestions have been made, but before taking these up it might be worth while to note that the first and second extensions of the Argelander system have never been adopted by the French. Ephemerides of variable stars were published in the *Annuaire* from 1877 to 1910, and after the first nine Argelander letters had been exhausted then these same letters with exponents were used, R^2 for *RR*, S^2 for *RS*, etc., up to Z^6 for the first extension of the Argelander system and up to R^{38} for the second extension. This system is surely cumbersome.

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[1] *Monthly Notices*, R. A. S. **25**, 66, 1865.

There are, I believe, three fundamental requirements that must be met in any system of variable star nomenclature which can hope for universal adoption. These are:

First—It must be simple.

Second—It must be capable of indefinite extension.

Third—It must not depend upon any particular epoch of time.

The Argelander system does not fulfill either of the first two requirements and is open to the further objection that it has not been made all-inclusive, such variables as *Algol*, *o Ceti*, *Polaris*, etc., never having been given symbols in the Argelander system.

The system of the *Annuaire* is surely not simple, and as the *Annuaire* no longer publishes ephemerides of variable stars, we need not perhaps give further consideration to this system.

The systems of CHANDLER and of PICKERING depend upon the epoch of 1900 and hence cannot fulfill the third requirement. There are other objections to them but we need not stop to consider them, as neither system is now being considered for universal adoption.

So much for the four systems which have been in actual use. If we grant that the three fundamental requirements mentioned above are reasonable and desirable, then it is evident that no system dependent upon letters can be satisfactory, for no such system is capable of indefinite extension. A system composed of a combination of letters and numbers, as exponents, subscripts or otherwise, is capable of indefinite extension, but is not simple.

My own suggestion would follow that made by CHAMBERS and also by ANDRÉ many years ago.[1] In 1865 CHAMBERS wrote, in publishing his second catalog of variable stars, as

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[1] *Monthly Notices*, R. A. S. 25, 208, 1865.

"ARGELANDER's nomenclature has been followed, but nifest that it is a very crude and unsatisfactory one, and at no very distant period will have to give place to something more artistic. Perhaps, on the whole, simple cardinal numbers, representing the order of discovery, with the syllable 'var.' and the name of the constellation appended, would be the most convenient and manageable system; e.g. 154 var. *Andromedæ.*"

I would suggest that the letter "v" be used in place of the syllable "var," and that the letter be placed before the number thus: v 154 *Andromedæ.* I would suggest that all variables be brought under this system; e.g. *Algol* = v 1 *Persei*, SS *Cygni* = v 20 *Cygni*, etc. If the suggested system be adopted it would be necessary, of course, at least in the first catalog issued, to print the old designation as well as the new, but after the present generation of astronomers has passed away such duplication of nomenclature would no longer be necessary.

It is readily seen that the proposed system satisfies the three requirements laid down. First, it is simple. Nothing could be simpler unless we leave off the letter "v," but this might cause confusion with the Flamsteed numbers. Second, the system can be extended indefinitely. Third, the system does not depend upon any particular epoch of time. I would suggest that the clusters and the Magellanic Clouds be considered as constellations, and that the variables in these be numbered separately from other variables of the constellations to which they belong. The letter "v" is the initial letter for the word variable in all the principal European languages—English, French, German, Italian, Spanish, Dutch, and perhaps others.

I had decided to make this suggestion before looking up the history of the subject. I do not mention this with the idea of trying to claim any credit whatever for the suggestion, but simply as an additional argument in favor of the plan. Any plan independently worked out by several persons must, I believe, have some merit to it.

Since above was written I have found that NIJLAND also independently made almost an identical suggestion, first in 1913,[1] and then repeated and actually used it in 1914.[2]

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[1] *Hemel en Dampkring*, **10**, 177, 1913.

[2] *A. N.* **199**, 209, 1915.

This second suggestion by NIJLAND brought forth a protest from HARTWIG,[3] who is in favor of retaining the Argelander system even to the extent of using the letters of the alphabet in combinations of three, which would add 2325 symbols. HARTWIG states two main objections to the proposed nomenclature, but neither, in my opinion, is very serious. The first objection is that the new designation would in all cases be longer than that of ARGELANDER. For instance R *Aurigæ* would become v 1 *Aurigæ*, a single letter being replaced by a letter and a figure; SS *Cygni* would become v 20 *Cygni*, two letters being replaced by one letter and two figures. HARTWIG's second objection is that the new nomenclature might lead to confusion in recording or interpreting, observations made by the Argelander method. For instance a variable *R* is observed and the result is a3R3b or a3Rb. In the new system this would be a3v13b or a3v1b. In the first case there would be an uncertainty as to whether v 1 is three steps brighter than *b* or v 13 is equal to *b*, and in the second case, whether v 1 equals *b* or *v*, the number designation having been omitted, is one step brighter than *b*. Now HARTWIG makes no mention of the constellation to which this supposed variable *R* or v 1 belongs, but in order that the observation may be complete this must be given and if we put the constellation in the record of the observation then there is no more ambiguity in the new system than in the old, thus, a3v1 *Aurigæ* 3b.

My own practice in recording observations by the Argelander method has been somewhat different and no uncertainty or ambiguity arises, no matter what system of nomenclature is used. I always write the name of the star first and then use simply the letter *v* in the observation, thus, in the old system, R *Aurigæ*, a3v3b or a3vb; in the new system, v 1 *Aurigæ*, a3v3b or a3vb. If this method of recording observations be used, and it seems to me both simple and logical, then HARTWIG's second objection has no force whatever.

STANFORD UNIVERSITY,
July 31, 1915.

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[3] *Vrtj. der Ast. Gesell.*, **49**, 201, 1914.

PROPER MOTIONS OF THE NEBULÆ.

By H. D. Curtis.

Particularly in connection with the radial velocities which have recently been found for a limited number of the nebulæ, a knowledge of nebular proper motions would be of great value in investigations as to the size and the distance of these bodies. It is most unfortunate that we have no old observations of nebulæ which can compare in accuracy with the positions of the stars determined a century or more ago, and which to-day form so valuable an asset in determining stellar proper motions. We have the element of time given us in the nebular observations made by the elder Herschel, but the probable error of his positions is a matter of minutes of arc, rather than seconds. Even when we come to the much more carefully made observations in the middle of the last century, any comparison of these positions with modern positions proves entirely illusory. Except for a very small number of sharply defined objects the older observations of the nebulæ are as valueless for the determinations of the motions of these bodies as are the old sketches in giving an adequate idea of their form and structure; photographic methods, plus the all-important factor of a sufficient time interval, will give us the only trustworthy data for the determination of nebular proper motions, as it has given the only trustworthy delineation of nebular forms.

It is now about sixteen years since Director Keeler inaugurated his program of nebular photography with the Crossley Reflector. It was early realized that this collection of photographs of 104 nebulæ and clusters was in many respects a unique one in its epoch and extent, and that it would some day serve as a valuable basis for determination of nebular motions or changes. One of the programs of work at the Lick Observatory has been to repeat the early photographs in the search for such changes, and also to collect as many additional photographs of nebulæ as possible to form the basis of more extended motion determinations in the future.

This program of repetition is now practically completed. The average time interval between the early and the late plates is 13.85 years: the total number of objects measured is 140 divided as follows:—

Large, diffuse nebulosities, *Orion*, *Network*, etc.	10
Planetary, annular and others showing gaseous spectrum (excluding diffuse nebulosities of the *Orion* type)	17
Very small nebulæ, most of which are probably spirals	47
Large spiral nebulæ	66

Inasmuch as both series of plates were taken with the same instrument, the methods of measurement have been made entirely differential, and, with the exception of one bright planetary for which no old plate existed, no attempt has been made to determine right ascensions and declinations and to compare thus with older visual observations. To some it may seem that thereby an opportunity has been lost, but such a procedure would have resulted in a considerable loss of accuracy. This loss in accuracy would come not only from the inaccuracy of the old visual observations, the probable errors of which are generally larger than the small motions to be determined, but also from the fact that even when sufficient comparison stars are found on the negatives, these stars, of the eighth or ninth magnitude, show such large images in exposures of two to four hours, that no very accurate settings can be made. Five or six symmetrically placed small stars of from the twelfth to the fifteenth magnitude were selected as a common reference system for all the plates of a given nebula, and the nucleus and numerous knots and condensations were measured as available in each nebula.

The accuracy of the measures varies considerably, from the nature of the case, in the different classes of nebulæ measured, and would be much higher were the old plates as uniformly sharp and good as the late plates. Owing to the deficiencies of the old mounting of the Crossley really excellent plates are the exception in the early series.

Quite a large proportion of the old plates, while adequate in giving the essential appearance of the nebulæ, would be rejected to-day. In making this statement I have no intention of belittling the work done by the early observers with the Crossley; a survey of all the older Crossley plates, with its large percentage of poor plates or absolute failures, tends give one a feeling of admiration at the pluck and determination of these observers in persevering and securing as good results as they did with a deficient and inadequate mounting. The problem resolves itself into making the best of the old series as it stands, inasmuch as for many of the nebulæ of this program a single plate taken by KEELER, PALMER or PERRINE forms the only existing photographic record prior to 1902.

The general results, by classes, are as follows:—

1. *Large, Diffuse Nebulosities.* This class includes such nebulæ as the *Orion*, the *Network* Nebula, the *Trifid*, M. 8 *Sagittarii*, etc. From the nature of the case the measurements on the delicate wisps, lanes, and holes in these complex and remarkable objects are very difficult, and the errors of measurement relatively large. For all ten objects the average relative yearly proper motion is 0.″036. This, of course, means very little; the most that can be said, both from the measures and from careful examination, is that there has pretty certainly been no change in any of the intricate formations of these enormous objects as large as one second of arc during the past fifteen years.

2. *Planetary and Annular Nebulæ.* Nearly all these have a very sharp stellar nucleus. The exposures necessary are only two or three minutes, and in many cases several images are available for measurement, so that the resulting proper motions seem entitled to greater weight than those of any of the other types of nebulæ measured. The average relative yearly proper motion for the seventeen objects in this class is 0.″028; the largest motions found are those for N. G. C. 6905 and 7009, 0.″056 and 0.″054 respectively.

3. *Very Small Nebulæ.* Only those were selected which showed a well marked central condensation or nucleus, and no attempt was made to get the faintest objects of this class. Many of them show faint evidences of spiral character, and probably the majority of them are in reality of this type. The average proper motion per year is 0.″040. It seems certain that none of these objects has moved as much as one second of arc during the past fifteen years.

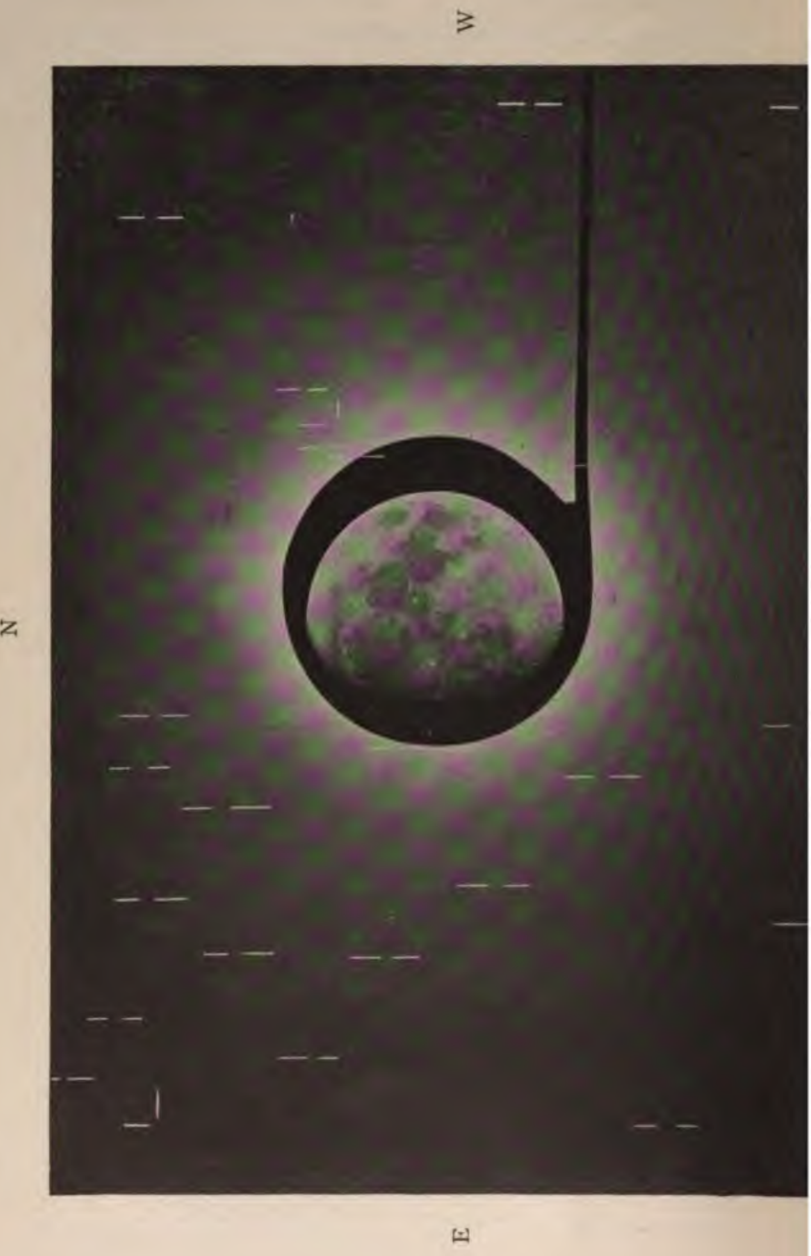
4. *Large Spiral Nebulæ.* The 66 objects in this class in-

clude not only the larger spirals, but also a number of lens-shaped objects which are doubtless spirals seen edge on. For ten objects it was found possible to make measures on the nucleus alone; for the others settings were made on from two to fourteen stellar condensations, which, tho generally hazy and indistinct, are beautifully sharp in a few cases. For some of the better spirals the agreement of the measures on the different condensations is quite good, and the motion seems well determined. Several spirals show a proper motion of six to nine hundredths of a second of arc per year, but these cases all occur where only a diffuse nucleus was measurable or where the old plate is distinctly poor; I have not, however, thot it best to reject these values. The nebula N. G. C. 253, in which nine condensations were measured on plates taken in 1902, 1907 and 1915, shows the largest proper motion in this class, which seems worthy of confidence, viz., —0."072 in $\alpha \cos\delta$ and +0."028 in δ. The average yearly relative motion for the 66 large spirals is 0."033. A number of the better determined nebulæ showing numerous condensations were examined graphically for possible evidences of rotation, but none were found. A much greater time interval will be necessary before nebular rotations can be definitely established by measures of position, unless a nebula abnormally close to us be found, and reliance must be had on spectroscopic methods, whose results are independent of the distance of the object.

Altho astronomical literature is already all too full of deductions made from an insufficient number of objects, it may be of interest to use the confessedly meager body of data at present available to obtain an estimate of the distances of the planetary nebulæ and the large spirals.

The average radial velocity of 73 planetary type nebulæ from recent Lick observations is thirty-nine kilometers per second. This value, combined with the average proper motion found, would make the average distance of this class of nebulæ about one thousand light-years, a value which is not improbable, as all these objects are Milky Way phenomena.

The radial velocities of very few spirals have been determined as yet; the mean of SLIPHER's results is 400 kilometers per truly enormous value, which may be considerably when a larger number have been determined. On s and on the assumption that these objects are moving truly at random in space, the average distance of the spirals is of the order of ten thousand light-years, a distance which many will regard as too small.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PRELIMINARY NOTE ON THE DETERMINATION OF THE POSITION OF THE MOON BY PHOTOGRAPHY.

By C. F. Adams.

The experiments described here were carried out at the ick Observatory, Mt. Hamilton, California, with the inten- on of ascertaining if satisfactory photographs could be cured of the Moon and surrounding stars, from which the osition of the Moon could be obtained with high accuracy.

The preliminary results are now submitted with the ap- roval of Director W. W. Campbell, to whom my thanks are endered for the facilities afforded me in carrying out these xperiments.

Quite a number of methods have been used in attacking his problem: some of them indirect, such as those of Major Hills,[1] and of Mr. E. B. H. Wade,[2] while of the direct ones those of Prof. H. H. Turner[3] and of Prof. H. N. Russell[4] re the best known. In Prof. Turner's method the light of he Moon is cut off from the plate by a rectangular focal plane hutter in which there is a narrow straight slit. The shutter s moved across the field at a uniform rate at right angles to he slit. The resulting image of the Moon is elliptical, owing o the motion of the slit. The stars are photographed on the est of the plate, which is fogged by the moonlight, but the ogging is not enuf to prevent accurate measurement.

Prof. Russell uses a very different arrangement: a cir- ular shutter is placed in front of and some distance away from the objective: the shutter is sufficiently large to cut off the whole of the moonlight from the plate and prevents fog- ging: but it also interferes with the star images which are

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[1] *Mon. Not. R. A. S.*, 58, 89.
[2] *Mon. Not. R. A. S.* 66, 45.
[3] *Mon. Not. R. A. S.*, 64, 10.
[4] *Harv. Obs. An.*, 72 No 1 and 76 No 7.

The illustration shows plate No. 25, July 22, 1915, Moon's age 10d.8, Moon's declination about −27°. Exposure on stars from 16h 42m 41s to 16h 50m 41s and on Moon from 16h 46m 4s.69 to 16h 46m 4s.92 Mt. Hamilton sidereal time. On the original negative all stars to 9.0 mag. in Cape Phot. D. M. are easily seen tho many are lost in the reproduction. Their positions are indicated thus: ; Three star positions indicated thus: ! –, are found the Cape, Edinburgh and Lick Zodiacal Catalogs (1900.0).

haped. The exposure on the Moon is obtained by turn.. he shutter momentarily on its edge.

The method used here differs from both of these and its essential features may be thus described: A circular shutter was used to cut off the direct light of the Moon from the plate; the shutter was placed just in front of the plate and slightly exceeded the Moon's image in size. An exposure was made on the field surrounding the Moon, with the Moon cut off by the shutter, and in the middle of the exposure the shutter was turned on its edge momentarily, thus giving an image of the Moon. The plate was fogged; but not enuf to prevent stars as faint as 10.0 magnitude being easily measured on a plate taken at full Moon.

The camera, with circular shutter and connections for the chronograph, was rigidly attached to the Crossley Reflector mounting. The lens is a doublet by Brashear, 4¼ inches aperture, 15 feet focal length, corrected for wave length 4500A; the rear surface is flat, and the front surface has a convex curve of 74.73 inches radius. The camera box is one foot square and about 15 feet 6 inches long, and it has diaphrams at about 5 feet and 10 feet from the objective. The circular shutter is 2 inches in diameter, and is placed just in front of the center of the plate. The plates used are Seed No. 27, 8 x 10 inches, and as the scale is one inch = 1149″, the plates cover about 2° 30′ in declination and $12^m 45^s$ (= 3° 11′) in right ascension on the equator.

The image of the Moon is about 1.6 inches in diameter, so that the shutter is large enuf to screen the Moon for an exposure of several minutes. All plates have been taken without guiding. Plates Nos. 27 and 28 are samples of the plates obtained by this method. They were taken on July 24, 1915, when the Moon was nearly full, the exposures were 6 minutes on the stars and 0.28 seconds on the Moon. On these plates five stars are seen, which are given in the Cape Edinburgh and Lick Catalogs (1900) of Zodiacal stars; while many other stars are easily seen ranging in magnitude to 10.0, and measurements can be readily made from them. These plates were exhibited at the meeting of the American Astronomical Society at Berkeley, California, in August, 1915.

The fogging of the plates is much less than was anticipated from the published accounts of experiments on this problem; and this may be due in some measure to the long focal length used (15 feet).

It will be noticed that in this method no interference is made in the optical train, and that in this respect it differs from the Harvard method, where the stellar images are affected by the screen used in front of the objective.

The experiments—which were made at all ages of the Moon—show that satisfactory plates can be secured even at full Moon, and that the fogging is not sufficient to prevent accurate measurement of the plates, provided a lens of long focus is used.

LICK OBSERVATORY, MT. HAMILTON, CAL.,
July 31, 1915.

OBSERVATIONS OF PERSEIDS IN 1915.

By Charles P. Olivier.

The study of meteors having been strangely neglected by astronomers, particularly in America, some years ago the idea came to the author that interest in their study could be best promoted by the formation of an association consisting of both professionals and amateurs. Accordingly late in 1911, while at Agnes Scott College, Georgia, with the assistance of several astronomers, who kindly exerted their influence to make it a success, I was able to first organize the American Meteor Society and have observations made on a systematic plan.

During the first four years the membership never exceeded twenty-five persons, of whom only twelve actually sent in results. Of these the larger part were members of the Meteor Section of the Society for Practical Astronomy, and, it should be added, these members sent in most of the observations. The results for the first three years, 1911 to 1913 inclusive, were completely worked up by the author and published under the title "126 Orbits of Meteor Streams" as Part 4 of Volume 2, *Publications of the Leander McCormick Observatory, University of Virginia.*

Last spring, in recognition of the importance of the results obtained by the Society and to increase its usefulness, the National Academy of Sciences generously voted a sum from the J. Lawrence Smith Fund, which has permitted a great expansion in the work. At the same time a series of articles by Dr. S. A. Mitchell and myself was published, asking for the assistance of all persons interested in meteors. The response was beyond expectation, over 100 new persons volunteering. As was to be expected, many of these, having once received the maps and instructions, apparently lost all interest. But on the other hand, the work, and in many cases work of a most excellent character, done by others, which has already been sent in, amounts to 1900 observations for July and August, 1915. This was done by twenty-one observers, situated in fourteen States and one in Canada. We have every reason to believe that others have succeeded in getting at least something, but have not yet communicated their results.

The most ambitious plan consisted of simultaneous observations of the *Perseids*, made at four stations, on August 9-13 inclusive, from 12 hours E. S. T. to 14 hours E. S. T. These stations were: Catholic University of America, Washington, D. C., Prof. ALFRED DOOLITTLE observing; Hampden Sidney College, Va., Prof. J. BROOKES SMITH; Richmond, Va., Prof. T. MCN. SIMPSON, and University of Virginia, C. P. OLIVIER. Bad weather prevented work on August 10th and 11th, but on the other three dates many apparent coincidences were observed! All four of the observers are now at work on the computations of the heights and paths of these meteors. It is hoped that some results of real value will be secured, tho the work was merely preliminary to future efforts in the same direction.

It is announced with special pleasure that Mr. R. M. DOLE of the U. S. Weather Bureau intends to put the whole of his observations at the disposal of the Society for publication. While partly published in small sections already, the results have never been wholly reduced nor the orbits computed. As he has observed over 5000 meteors, this will make a great and valuable addition to the literature of Meteoric Astronomy.

The labor of preparing the many thousand observations already on hand and those expected in the near future is so great that definite results cannot be published for some little time. In the interval regular reports will appear in *Popular Astronomy* and elsewhere, in which the observer's name will appear, and the amount of work done by each will be duly accredited to him.

Even yet there must be many amateurs who would gladly help in our work if they realized that it was of actual scientific value. Our program for the observations of meteors offers the opportunity to all such persons.

We are now able to furnish maps, blanks and detailed instructions to all who apply. Observers and many observers are needed everywhere. If one cannot work except a few nights per year, we are still glad to have his assistance, and his work, if done in accordance with instructions, will be valuable. Training can only be acquired by experience, so

it need deter no one. A cordial invitation is exte
one interested to write for further information to
address given below. As we are very short of observe
the West, we hope that many members of the Astrono
Society of the Pacific will communicate with us with a
to assisting.

LEANDER McCORMICK OBSERVATORY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, VA.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1916.

By Malcolm McNeill

PHASES OF THE MOON, PACIFIC TIME.

New Moon ... Jan.	4, $8^h\ 45^m$	P.M.	New Moon ... Feby.	3, $8^h\ 6^m$	A.M.
First Quarter. "	11, 7 38	P.M.	First Quarter. "	10, 2 20	P.M.
Full Moon ... "	20, 12 29	A.M.	Full Moon ... "	18, 6 29	P.M.
Last Quarter. "	27, 4 35	P.M.	Last Quarter. "	26, 1 24	A.M.

There will be five eclipses during 1916, three of the Sun and two of the Moon.

The first, *a partial eclipse of the Moon* on the night of January 19-20, will be visible generally thruout the United States. The circumstances of the eclipse are as follows, Pacific Time:—

Moon enters penumbra	January	19, $10^h\ 5^m$	P. M.
Moon enters shadow.........	"	19, 11 55	P. M.
Middle of the eclipse.........	"	20, 12 39	A. M.
Moon leaves shadow	"	20, 1 24	A. M.
Moon leaves penumbra	"	20, 3 14	A. M.

The greatest magnitude of the eclipse is about one-eighth of the Moon's diameter.

The second is *a total eclipse of the Sun* on February 3d, visible as a partial eclipse thruout the greater part of North and South America, Western Europe and Northwestern Africa. The line of totality begins at sunrise in the Pacific Ocean, runs nearly due eastward, crossing the extreme northwestern part of South America a few miles south and east of Panama, thence northeastward across the Atlantic, ending at sunset westward of the English Channel. The maximum duration of totality is small, $2^m\ 36^s$.

On the night of January 14-15 the Moon will occult a number of stars of the *Pleiades* group, the immersions coming at the dark limb.

At the beginning of January *Mercury* is an evening star, setting not quite forty minutes after sunset. Its apparent distance from the Sun increases somewhat rapidly, and by the middle of the month the interval has increased to an hour and one-half. The planet will then be an easy naked-eye object in the evening twilight. Greatest east elongation is reached on January 20th, 18° 40′, rather a small one, as the date of perihelion passage is less than a week later. This also causes a diminution of the period of naked-eye visibility, as the planet's motion when near perihelion is rapid. After greatest east elongation the gap between planet and Sun closes up rapidly, and inferior conjunction is reached on February 4th, the planet becoming a morning star. The apparent distance between Sun and planet now increases rapidly and greatest west elongation is reached on March 1st. During the latter half of February the planet rises more than an hour before sunrise, and may be seen in the morning twilight under good weather conditions.

Venus is an evening star gradually moving eastward from the Sun. On January 1st it sets a trifle more than two hours after sunset, and this interval is increased to more than three hours by the end of February. Its motion among the stars is rapid, rather more than one degree a day eastward, and not quite half as much northward. It is in rather a barren region of the sky, moving from a point in *Capricorn* thru *Aquarius* to the eastern part of *Pisces*. On February 13th it passes not quite 1° south of the Vernal Equinox, and a few hours later is in conjunction with *Jupiter*, the latter being 27′—less than the Moon's apparent diameter—to the south.

The present two months' period affords the best view of *Mars* since January, 1914. The planet comes to opposition with the Sun and makes its nearest approach to the Earth on February 9th. On January 1st it rises a little earlier than 9 P. M., and by the end of February shortly after 3 P. M. From January 1st until nearly the end of March its motion among the stars is retrograde, that is westward; at the end of February its position is 17° west and 6° north of its January 1st place. On February 9th, at the time of opposition, its distance from the Earth is a little less than 63 millions of miles, 14 millions less than on January 1st, and 4 millions less than on March 1st. At opposition its brightness in stellar magnitude is -- 1; this is more than twice as bright as it was on January 1st, and this was about twice as bright as *Regulus*, the bright star near it in early January.

The present opposition is about the most unfavorable which can occur, as it comes when *Mars* is near aphelion, while the Earth is near perihelion. When opposition occurs in August the conditions are reversed. The next August opposition occurs in 1924. The least distance between Earth and planet will then be less than 35 millions of miles, only 55% of the present opposition distance, and the planet will then be three times as bright as it is in February. The interval between successive oppositions varies from a little over 760 days for winter oppositions to a little more than 800 days for summer oppositions. The next opposition will occur March 15, 1918, 764 days after the present one.

Jupiter is an evening star thruout January and February. On January 1st it sets a little before eleven o'clock and shortly after eight at the end of February. It is in the constellation *Pisces* and moves about 11° eastward and 5° northward during the two months. On February 9th it passes a little more than 2° south of the Vernal Equinox. Its conjunction with *Venus* on February 13th has been mentioned. *Venus* will then be more than a full magnitude brighter than *Jupiter*.

Saturn is in fine position for evening observation, coming to opposition with the Sun on January 9th. It is then above the horizon throughout the entire night. [illegible] at about [illegible] in the [illegible] the brighter [illegible] the [illegible] the brighter of the two. [illegible] of the rings [illegible] than the polar diameter of the planet.

Uranus [illegible] near [illegible]

Neptune [illegible] the greatest [illegible] seen without a telescope.

NOTES FROM PACIFIC COAST OBSERVATORIES.

NOTE ON THE REMEASUREMENT OF THE A DOUBLE STARS.

Before publishing a general catalog of the A double stars it is planned to secure a set of measures of each pair at a second epoch. This will indicate not only which pairs are in need of frequent observation, but will also serve as a check upon the earlier measures and identifications. Systematic remeasurement was begun in July of the present year, and, including a few pairs remeasured in 1914, 420 pairs have now (November 4th) been completed. These pairs lie mainly in the third, fourth and first quadrants of the zones 0° to — 10°, + 56° to + 90°, and + 4° to + 12°.

The history of the double stars listed in earlier catalogs led to the expectation that only a small percentage of the A stars would give definite evidence of relative motion in the interval of from 10 to 16 years between the two sets of measures. A comparison, for example, of the measures by DEMBOWSKI and STRUVE of the 405 Σ double stars of Orders I and II (pairs with angular separation of less than 1″ and from 1″ to 2″, respectively) shows that in the interval of 30 or more years only 88 (21.7%) changed as much as 10° in position angle, and only 37 (9.1%) as much as 20°. My 420 remeasured pairs include many that are considerably closer than the closest of the Σ stars, but also 127 that range from 2.″00 to 5.″50 in distance.

In point of fact, 358 of the pairs show an angular change of less than 5°, the average, without regard to sign, being ± 1.°6. Thirty-one of these pairs have an angular separation of 0.″50 or less, the average for all 358 being 1.″81. The distance measures during the present year are systematically larger than at discovery, the average algebraic difference for the 358 stars being + 0.″047. Disregarding the sign the average difference is ± 0.″066. While it is quite probable that in some instances the changes observed are due to actual motion, these average differences— ± 1.°6 and ± 0.″07—may be regarded as an index to the consistency of the measures.

Probably some of the observed changes in excess of 5° in the 62 remaining pairs are due to error of measure, but it is believed that in the majority of cases, and quite certainly in the 37 pairs in which the difference is as great as 10°, the observed change indicates real motion.[1]

In general these are all close pairs, the distance, except in four instances, ranging from 0.″14 to 0.″83. The wider pairs are:—

Star	Δ Epoch.	Δ θ	ρ disc.	ρ₁ — ρ	Mag.
A 14	16.0	+ 8.°3	3.″76	— 0.″69	9.0 — 12.0
111	15.0	— 5.3	2.13	+ 0.17	8.6 — 12.5
146	14.2	— 6.2	1.82	0.00	7.5 — 10.0
1229	9.8	— 5.4	1.40	— 0.25	9.1 — 13.0

The change in A 14 and in A 1229 may be due to the proper motion of the primary, but these stars are not given in any proper motion lists available to me. A 111 and A 146 are well-known proper motion stars. PORTER (*Cinn. Publ.* 12) gives the motion of A 146 as 0.″14 in 155.°5, which would *increase* both the position angle and distance of the companion if independent. My measures are:—

Date.	θ	ρ	n
1901.27	308.°0	1.″82	3
1906.38	305.2	1.84	2
1911.29	302.9	1.82	1
1915.44	301.8	1.90	1

The angular change is therefore probably due to orbital motion. In the case of A 111 the evidence for orbital motion is even stronger. According to PORTER (*Cinn. Publ.* 18), the proper motion of the primary is 0.″285 in 97.°7 and hence, if the companion were independent, its position in 1915 should be about 5.″5 in 257° from the primary. The following measures show the actual relations:—

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[1] It must not be forgotten that the measures at both epochs were made by the same observer and with the same telescope. A difference even of 10° would not necessarily imply actual motion if the second measures had been made by a different observer under different conditions.

Date.	θ	ρ	n
1900.71	212.°6	2.″13	3
2.67	212. 1	2. 26	2
4.96	210. 6	2. 30	1
6.81	209. 4	2. 22	2
8.97	209. 6	2. 05	1
11.84	209. 2	2. 19	2
1915.71	207. 3	2. 30	2

On the first night's examination in the present year I found the primary to be a very close double, measures on the two nights giving the position:—

1915.71 262.°5 0.″22 9.3 — 9.3 magnitudes

The seeing was good on many of the nights in earlier years when the wider pair was measured, and the close pair could hardly have escaped detection if the angular separation had been as great as it is now. This is undoubtedly a triple physical system.

Another wide pair deserving special mention is A 53. PORTER (*Cinn. Publ.* 18) assigns the primary the large proper motion of 0.″72 in 78.°1, and SMITH (*Yale Publ.* II, pt. 3) obtains a parallax of + 0.″067 ± 0.″015. My measures are:—

Date.	θ	ρ	n
1900.20	45.°6	4.″94	2
1904.08	44. 8	4. 69	1
1915.81	43. 7	4. 20	2

The magnitudes are 8.5 and 12.5. Assuming the correctness of the first position, the proper motion would place the companion at the time of the last measures in 268° ±, 7.″6 ±, if the two stars were independent. There is little doubt but that the observed change is due to orbital motion.

Of the closer pairs, I shall here list only those in which the angular change exceeds 40° and three which with smaller angular motion have shown also marked change in distance. Attention has been called to three of these stars— A 88, A 417, and A 570—in earlier numbers of these Publications:—

Star.	Δ Epoch.	Δ θ	ρ disc.	$\rho_1 - \rho$	Mag.
A 1	16^{y}.0	+ 24.°4	0.″31	+ 0.″15	8.2 — 8.3
A 88	15 .1	— 406. 8	0. 14	+ 0. 01	6.9 — 7.1
A 93	15 .1	+ 56. 8	0. 28	— 0. 03	9.0 — 9.3
A 235	14 .2	+ 20. 2	0. 20	+ 0. 17	7.9 — 8.1
A 313	13 .0	— 29. 2	0. 19	+ 0. 09	8.4 — 8.8

Star	Δ Epoch.	Δθ	ρ disc.	$\rho_1 - \rho$	Mag.
A 417	13.0	−146.5	0.19	−0.03	6.0—6.0
A 431	12.6	−84.8	0.19	−0.04	8.5—8.5
A 564	12.0	−159.0	0.14	−0.03	6.9—7.8
A 570	12.2	−119.6	0.20	−0.02	6.3—6.5
A 606	12.3	−41.1	0.28	−0.02	8.8—8.8
A 632	11.9	−30.8	0.45	−0.11	8.0—8.7
A 693	11.0	−49.8	0.19	−0.02	9.0—9.0
A 751	10.2	−67.5	0.16	−0.03	6.8—7.3
A 883	10.9	−227.4	0.14	−0.02	7.6—7.8
A1014	9.9	−40.1	0.25	−0.10	8.6—8.6
A1238	10.2	−46.7	0.25	−0.01	7.4—7.6

It is practically certain that the motion in all of these systems is orbital. A 751 is too close to measure this year, and the two measures last year were made with great difficulty and are discordant. The change of 227° in A 883 is assigned on the evidence in intermediate years that the motion is retrograde. This year the quadrant was indeterminate.

Robert G. Aitken.

November 4, 1915.

The Remodeled 60-foot Tower Telescope.

In its original form, the 60-foot tower telescope was constructed as cheaply as possible, using a single standard water-tank tower built by the Aermotor Company, and small canvas-covered shelters for the coelostat and second mirror. Its very satisfactory performance made a more permanent arrangement desirable, and it has accordingly been provided with a second tower, supporting a dome, and a closed tube, with double walls, extending from top to bottom and thus protecting the vertical light beam from cross currents of warm air near the ground. The temporary house at the foot of the tower has also been replaced by a concrete structure, enlarged sufficiently to give space for a photographic dark-room.

At the same time various important changes have been made in the auxiliary equipment. The 30-foot spectrograph, improved in various details, may now be easily transformed into an 18-foot spectrograph for use with a quartz invar interferometer. It has also been provided with vacuum and mercury arcs, a device for exposing simultaneously on the arc and solar image, and other new accessories. A 13-foot spectro-heliograph has also been constructed and installed beside the spectrograph. The frame of angle iron which supports the optical parts is suspended in the underground chamber from a heavy carriage resting on four steel balls, moved as a whole by an electric motor. Thus the solar image and photographic plate are stationary, while the collimator and camera slits move with the spectro-heliograph across them. The 4-inch plane grating used in this instrument, which is extremely bright in the first order, was ruled by ANDERSON. As the axes of the collimator and camera lenses are parallel, the beam, after leaving the grating, falls on a plane mirror, from which it is reflected thru the camera lens. This mirror may be moved along the axis of the camera lens, thus making it possible to change the angle between the incident and diffracted beams and hence to vary the linear dispersion of the first order spectrum.

In work with the spectro-heliograph it is often desirable to determine small displacements of flocculi not measureable by existing methods, because of local distortions due to drift of the image during the exposure, temporary poor seeing, changing refraction during long exposures with low sun and other causes. The 13-foot spectro-heliograph is accordingly provided with two camera slits, one of which may be set on *Hα* or any desired line), while the other, at a distance of several inches, is set on the continuous spectrum. Thus two images of the same region of the Sun may be photographed simultaneously on a single plate, one showing the flocculi surrounding a group of sun-spots, the other the spots themselves. Fine wires stretched across the collimator slit, together with the images of the two camera slits at the end of the run, furnish the necessary fiducial lines, with reference to which the positions of spots and flocculi can be measured. Thus the motions of flocculi can be determined differentially with reference to spots on solar images affected in precisely the same degree by any source of distortion.

By providing two gratings or two mirrors below the camera lens, two images of the spectrum from a single collimator slit can be produced side by side. Thus by setting one camera slit on the red edge of *Hα* in one spectrum and a second camera slit on the violet edge of *Hα* in the other spectrum, photographs of flocculi can be obtained with the two edges simultaneously. Similarly two or even three photographs, showing sections of the flocculi at as many different levels, can also be taken simultaneously.

The results obtained with the 13-foot spectro-heliograph are very satisfactory, showing the advantages of improved definition of the solar image, high dispersion and freedom from diffuse light in the spectro-heliograph and exceptional smoothness of motion. Successive photographs of the disk made with the $H\alpha$ line, when combined in a stereoscope, show the flocculi standing in high relief, and clearly indicate the identity of the very dark hydrogen flocculi (called "filaments" by DESLANDRES) with prominences, in which form they are subsequently photographed when carried to the limb by the Sun's rotation.

GEORGE E. HALE.

PROGRESS OF WORK ON THE 100-INCH TELESCOPE.

The close of the 1915 construction season finds the steel dome for the 100-inch telescope completely enclosed and in working order, tho considerable miscellaneous work remains to be done. This includes the exterior sheathing of the fixed portion of the building (the inner wall of which is in place), the construction and erection of the observing platform and cage-hoist, exterior and interior painting, etc. It is satisfactory to find that the dome turns very smoothly and easily on the rails, which were finished true after erection with a high-speed grinder carried by a radial arm pivoted at the center of the building. This is a matter of importance, as the high dispersion spectrograph for stellar spectra, to be mounted on a pier in line with the polar axis, must be free from vibration during the very long exposures which will be required.

Two carloads of parts of the telescope mounting are already on Mount Wilson and four carloads are on the way from the Fore River Ship Yards at Quincy, Massachusetts, where the heavier work has been done. The balance will follow very soon, excepting the tube, which was to come by the Panama Canal, now closed to traffic because of slides. Many of the smaller parts of the mounting, including the driving clock, have been completed in our Pasadena instrument shop.

parabolizing of the 100-inch mirror is progressing satisfactorily in our optical shop, and is now 85 per cent complete. The optical tests for figure are made both at the center of curvature and at the focus of the paraboloid, in the latter case with the aid of a 60-inch plane mirror figured for the purpose.

The erection of the telescope mounting on its pier will be begun in 1916, after the completion of some unfinished work on the larger parts and the painting of the interior of the dome. It is not likely that the telescope can be ready for use before the summer of 1917.

George E. Hale.

The Spectrum of the Companion of Sirius.

We have made several attempts during the past two years to secure a spectrum of the companion of *Sirius*. Its position is favorable, the distance, according to Professor Barnard's recent measures, being more than 10″ in a position angle of about 70°. The great mass of the star, equal to that of the Sun and about one-half that of *Sirius*, and its low luminosity, one one-hundredth part of that of the Sun and one ten-thousandth part of that of *Sirius*, make the character of its spectrum a matter of exceptional interest.

Most of the spectrum photographs have been taken at the 80-foot focus of the 60-inch reflector with the Cassegrain combination of mirrors. At this focus the distance of the companion from *Sirius* is 1.2^{mm}. The rays from *Sirius*, due to the supports of the auxiliary mirrors, are very prominent, but form angles of about 45° with the line joining *Sirius* with the companion, and so do not reach the slit unless the images begin to blur badly. The main difficulty in securing satisfactory photographs is, of course, the strong general illumination of the field and the presence of subsidiary rays which contribute more or less light to the slit as the seeing varies. During the exposures *Sirius* has been kept on the black metal screen in which is cut the opening forming the star window, while the companion is held in a position slightly to one side of the center of this window. Accordingly it is possible to compare on the photographs the spectrum of the point at which the companion is maintained with the spectrum due to the general illumination of *Sirius*. The exposure times given have been those normal for a star of 8.5 magnitude.

Two or three photographs obtained in this way showed a decided maximum in the spectrum at the point at which the companion was kept during the exposure. Still there was no distinct line of separation from the general spectrum due to *Sirius*. A photograph taken on October 18th under exceptionally good conditions of seeing does show such a demarcation, however, there being a narrow spectrum corresponding to the point on the slit at which the companion was held, which is separated by a distinct break from the intense spectrum of *Sirius* near the edge of the star window. It is difficult to avoid the conclusion that this is the spectrum of the companion. There was no ray from *Sirius* near this point of the slit and during the entire exposure the companion was well visible and accurate guiding was easily maintained.

The line spectrum of the companion is identical with that of *Sirius* in all respects so far as can be judged from a close comparison of the spectra, but there appears to be a slight tendency for the continuous spectrum of the companion to fade off more rapidly in the violet region. The suggestion has been made by several astronomers that at least a portion of the light of the companion is due to light reflected from *Sirius*. It is, however, by no means necessary to have recourse to this explanation, since in the case of the companion of o_2 ***Eridani***, where there can be no question of reflected light, we know of a similar case of a star of very low intrinsic brightness which has a spectrum of type A_0.

Direct photographs taken by Dr. VAN MAANEN with and without the use of a yellow color screen agree with the spectrographic results in indicating that the companion of *Sirius* has a color index not appreciably different from that of the principal star.

WALTER S. ADAMS.

THE SPECTRUM OF NOVA LACERTÆ (1910).

Two photographs of the spectrum of this Nova were obtained on the nights of September 3d-4th and September 5th-6th with a small slit spectrograph at the primary focus of the

60-inch reflector. The exposure times were about 16 hours in each case, with a slit width of 0.04^{mm}.

The photographs show that the intensities of the continuous spectrum and of the bright hydrogen lines remain nearly the same as on a photograph secured in October, 1913. The nebular lines, however, are very much fainter, the chief nebular line being now of nearly the same intensity as $H\beta$. It is evident that the spectrum of *Nova Lacertæ*, like that of *Nova Persei* and *Nova Geminorum* No. 2, is developing into the Wolf-Rayet type.

A direct photograph, upon which was superimposed a photograph of the polar sequence, gives a photographic magnitude of 13.5 for the star.

WALTER S. ADAMS,
FRANCIS G. PEASE.

A SEVENTH VARIABLE STAR IN THE HERCULES CLUSTER.

In *Astrophysical Journal*, **40**, 179, 1914, Professor BARNARD calls attention to a star in the cluster Messier 13, midway between Scheiner Nos. 231 and 270, which seems to be a variable. The star is evidently Scheiner No. 245 = Ludendorff No. 344. The Mount Wilson plates confirm the suspected variation, tho but a small change in brightness is recorded.

The observations are as follows:—

Date.	Photographic Magnitude.
1914, August 23d	14.8
September 18th	15.0
September 19th	15.2
October 18th	15.1
1915, March 15th	14.7

HARLOW SHAPLEY.

NOTE ON THE SPECTRUM OF STARS OF HARVARD TYPES N AND R.

The very interesting type of stellar spectrum discovered by Mrs. FLEMING and designated as type R was distinguished by her from that of type N by the relatively great intensity of the violet portion of the continuous spectrum. In a recent comparison of the spectrum of the brightest representative of this type, B. D. — 10°5057, with that of several stars of type N, some other differences have been found which may have a bearing on the relation of these two types of spectra to one another. The principal differences may be summarized briefly as follows: the well-known N type star, B. D. + 25° 205 is taken as representative of this class.

	B. D. + 25°205 (N)	B. D. — 10°5057 (R)
"Carbon" heads 4554, 4606...	Very strong	Trace
λ 4744, 4934	" "	Absent
λ 4227 (Ca)	" "	Weak
Arc lines of Ti and V....... (Strong in sun-spots.)	Strong	"
Enhanced lines of Fe and Ti. (Weak in sun-spots.)	Weak	Strong
Chromospheric lines λ 4215, λ 4233	Weak	Very strong

It is evident that these differences, tho greater in amount, are very similar to those found between the spectrum of sun-spots and that of the Sun. The intensity of the violet portion of the continuous spectrum, the strength of the chromospheric and the enhanced lines, and the weakness of the low temperature lines such as λ 4227 of calcium, all point to the probability of a distinctly higher temperature for the R type stars.

WALTER S. ADAMS.

RADIAL VELOCITIES OF SIX NEBULÆ.

Spectrograms of the following nebulæ have been taken with the 60-inch Cassegrain spectrograph in which a 64° O 102 prism and camera of 7 inches focal length were used. The scale is $H\gamma — K = 7^{mm}$.

The plates were measured by Mr. ADAMS and values given are reduced to the Sun.

1. *Dumbbell Nebula.*—The slit was set on the brightest knot in the nebula about 1¾ minutes of arc *sp* the nucleus. The exposure was 32½ hours, extending over five nights. Four strong bright lines show; 5007, 4959, $H\beta$ $H\gamma$; no continuous spectrum shows. The radial velocity is $— 63^{km}$.

2. *Messier* 33.—The slit was set on the brightest knot in the nebula about 10 minutes *nf* the nucleus. The exposure was 34½ hours. Three bright lines only appear, 5007, $H\beta$, $H\gamma$. The radial velocity is $— 278^{km}$.

3. *N. G. C. 7023*—*a)* 7th mag. star involved in nebulosity. The radial velocity for the nucleus given by four absorption lines is $+ 0.7^{km}$. *b)*. Two spectrograms of the nucleus obtained with the slit spectrograph in the primary focus of the 60-inch reflector and with the slit (p-f) 13.6 seconds of arc north of the nucleus both show the same strong continuous spectrum crossed by absorption lines.

4, 5, 6. *N. G. C. 6572, N. G. C. 6826, N. G. C. 6891.*—Planetary nebulæ. Radial velocities are:—

N. G. C. 6572 (9 lines)	-12^{km}
N. G. C. 6826 (5 lines)	-8
N. G. C. 6891 (6 lines)	$+38$

The values which KEELER obtained for these nebulæ as mentioned by CAMPBELL in "Stellar Motions," p. 210, are:—

N. G. C. 6572	-9.7
N. G. C. 6826	-5.3
N. G. C. 6891	$+40.7$

WRIGHT'S values of nebular wave-lengths were used.

FRANCIS G. PEASE.

FAINT STAR WITH LARGE PROPER MOTION.

Three pairs of plates taken in 1914 and 1915 of the region of Pi. 2^h 123 ($\alpha = 2^h\ 30^m\ 36^s$, $\delta = +6° 25'$, 1900) show a star of about the 12th magnitude, 2'.6 East, 0'.9 South, having a proper motion of 2''.63 in p = 48°.9, which is nearly the same as that of the principal star (2.''34 in p 51°.8).

Assuming the parallax of the faint star to be the same as that of Pi. 2^h 123, which is given in *Publication of the Astronomical Laboratory at Groningen*, No. 24, as + 0''.143, the absolute magnitude (apparent magnitude at a distance corresponding to parallax 0''.1) of the faint star is about 13.

A. VAN MAANEN.

RADIAL VELOCITIES OF THE PLANETARY AND IRREGULAR NEBULÆ.

The discovery in 1910 that stellar radial velocities increase in general with advancing spectral class has led to the extension of the observing program to include the gaseous planetary and extended nebulæ whose spectra are composed of bright lines, a particular point of interest in the results to be obtained being possible relationships between nebular and stellar velocities which might lead to conclusions respecting the hypothesis of the evolution of stars from nebulæ. Three hundred and forty-eight measures of the velocity of 92 nebulæ have been secured at the Lick and D. O. Mills Observatories, working respectively in the northern and southern skies. Single prism spectrographs with cameras of 16 and 18 inches focal length have been used for the brighter objects, particularly the planetary nebulæ, but for the fainter and extended nebulæ, two- and three-prism instruments with 8- and 5-inch cameras have been employed. The advantage of the latter combinations is obvious from the fact that the 3-prism spectrograph, for example, is found to be five or six times as rapid as the one-prism, long-camera instruments, while the linear dispersion is the same. By means of these combinations the two green lines of nebulium and the hydrogen line H^{β} and occasionally the line at 4686 A have been photographed with exposures ranging from one to 18 hours. The measures of velocity obtained from the plates show probable errors ranging from one to four kilometers, depending upon the intensities and number of lines measured.

The results deduced from the observations depend upon 80 out of the total 92 values of velocity, 12, which relate to nebulæ in the Magellanic Clouds, having been excluded because attended by extraordinary circumstances. Seven pertain to the extended or irregular nebulæ and 73 to the regular forms as planetary and annular. All velocities having been freed from the effect of the solar motion, average velocities of the various groups are found to be:—

Of	7 extended nebulæ	10 kilometers
"	39 disks and rings	29 "
"	34 stellar nebulæ	50 "
"	73 regular forms	39 "

From this it is obvious that velocity increases with respect to the order: extended, disk, stellar forms. It can scarcely be questioned that the planetary nebulæ may become helium stars, but the hypothesis that helium stars, whose radial velocities thus far observed average 6 kilometers, have in all cases evolved from planetary nebulæ appears untenable in view of the six- or seven-fold greater average velocity of planetary nebulæ.

A further significant result is the accordance of the value of the solar motion derived from these nebular velocities with that of 20.2 kilometers derived from Class B stars: namely, 20.1 kilometers from the 73 nebulæ of regular form, and 20.7 kilometers from the 7 extended nebulæ. It is thus clear that the extended and planetary nebulæ are associated, at least in respect to their peculiar motions, with our stellar system. The evidence of association of the nebulæ with our stellar system is strengthened by strong indications of preferential motions in the direction of the vertices of Kapteyn's two star streams. This is shown in two ways, first by a tabulation with respect to distance from the vertices and second with respect to distance from the central plane of the Milky Way.

W. W. Campbell,
J. H. Moore.

Note on Hind's Variable Nebula.

This nebula (N. G. C. 1554), close to the irregularly variable star T *Tauri*, is an object of special interest in that it affords us probably the only absolutely authentic evidence of change in this class of objects. It was discovered by Hind in 1852, and was seen easily and measured by Struve, D'Arrest, Lassell, and others, but had disappeared by October, 1861. The various observations are so definite that there is no chance for error. D'Arrest, for instance, describes it as quite bright, about 1′ in diameter, and saw it easily in the light of the five-day-old moon. In 1890, Professor Barnard described it as at the limit of visibility with the 36-inch refractor.

Five plates have been taken of this region with the Crossley Reflector; the dates and exposures are:—

1899, December 6th, exposure	3^h 52^m
1899, December 27th, "	4 00
1914, March 27th, "	1 20
1914, November 16th, "	3 00
1914, November 20th, "	2 30

The nebula is of the utmost faintness on all these plates, but is apparently a little brighter in 1914. It is difficult to resist the impression that it has become somewhat brighter, tho the rather poor character of the plates of 1899 makes a definite decision impossible.

The star T *Tauri* itself has a very interesting nebulous wing which is either variable or must rotate so as to be concealed at times. This appendage is a small cone-shaped projection perhaps four seconds of arc in length in position angle 150 ± °. It was often seen by TEMPEL, and was fairly conspicuous when examined by BARNARD and BURNHAM in 1890, but entirely invisible when BARNARD looked for it in February, 1895. It can be clearly made out in the elongated image of T *Tauri* on both the Crossley plates of 1899. On the 1914 plates it is certainly not present; the disk of the variable is perfectly round, tho perhaps with just a trace of nebulosity all around it. It is evident that this interesting variable will repay further investigation. H. D. CURTIS.

SEARCH FOR FAINT MEMBERS OF THE TAURUS CLUSTER.

Dr. HERTZSPRUNG suggested in 1914 that it would be of interest to compare the earlier plates of the region of T *Tauri* with recent plates in the endeavor to find very faint members of the well-known Taurus stream. This region is about five degrees from the center of the *Hyades*, and a proper motion of 1″6 would be expected in the interval of nearly fifteen years. A motion of this amount should show clearly on the Crossley plates.

The measures were made entirely differential, with respect to a common system of five stars of eighth to ninth magnitude; and twelve faint stars of from fourteenth to eighteenth magnitudes were selected at random in the area of best definition. None of the small relative motions found agree either in magnitude or direction with the motion of the components of the Taurus stream. Within the limited area examined the results must be regarded as purely negative.

H. D. CURTIS.

NOTE ON COMET *d* 1915 (MELLISH).

Comet *d* 1915 was first seen by Mr. JOHN E. MELLISH, of the Yerkes Observatory, on September 13, 1915.

The first observation received at the Students' Observatory was one by Dr. AITKEN, taken on September 20th. Another observation on September 21st by AITKEN, and one by VAN BIESBROECK at the Yerkes Observatory, on September 18th, arrived the following day. On the basis of these three observations a preliminary orbit was computed by Mr. ALTER and the undersigned. (H. C. O. Bulletin 590). Four more observations have been received to date: two by AITKEN on September 22d and 23d respectively, and two by VAN BIESBROECK on September 20th and 21st respectively. AITKEN'S observations of September 20th, 21st and 23d were used in the calculation of new elements, which are published with an ephemeris in Lick Observatory Bulletin, Number 273.

The comet passed within 41,000,000 miles of the Sun on October 13, 1915. Its nearest approach to the Earth occurred on October 2d, when it was approximately 123,000,000 miles away. It changed from a morning to an evening object on October 6, 1915. The inclination of its orbit plane to the ecliptic is 54°. The longitude of its ascending node is 78°. This places the path of this comet in a plane nearly coincident with that of comet *a* 1915, discovered by MELLISH on February 10, 1915.

Owing to its rapidly increasing southern declination, and nearness to the Sun, it is doubtful if any more observations of the comet can be secured in the northern hemisphere. Lick Observatory Bulletin, Number 273, gives its position to December 30, 1915. Its declination on that date is — 49°, and in right ascension it is, at that time, only one hour east of the Sun. Its distance from the Earth on December 30, 1915, will be 239,000,000 miles.

S. EINARSSON.

STUDENTS' OBSERVATORY,
UNIVERSITY OF CALIFORNIA,
November 3, 1915.

NOTE ON COMET *d* 1915 (MELLISH).

A telegram was received at the Lick Observatory on September 19, 1915, from Director FROST of the Yerkes Observatory requesting observations of a new comet discovered by Mr. JOHN E. MELLISH. The comet was found that night with the 12-inch telescope. It was a small object, nearly round, about 3′ in diameter, with a well marked central condensation, hardly sharp enuf to be called a nucleus. It was low in the eastern sky just before dawn, and its motion was found to be to the south and east, towards the Sun. Measures were not difficult on this night nor on September 20th, for the observing conditions were good. On the two following nights, September 21st and 22d, wind and poor seeing, and moonlight made the comet exceedingly faint. On September 21st no star was available for direct measures, and the approach of dawn permitted only four measures in each co-ordinate, by transits, from a star nearly 2^m distant. This observation should be given small weight in the definitive orbit discussion. Strong moonlight and the comet's rapid approach to the Sun prevented further measures. It was looked for in the western sky after sunset in October, but without success.

R. G. Aitken.

November 8, 1915.

A Brilliant Aurora.

In the early morning hours of June 17, 1915 (civil time), a beautiful aurora was seen from Mount Hamilton. It was first noticed shortly after midnight and became most brilliant at about 2:30 (P. S. T.). The illumination extended from 15° to 30° west of north to 80° or 90° east of north. The streamers reached half way to the zenith,—up into the Milky Way about *Cassiopeia*. Few of the streamers were as long as 60°, and the forms were changing constantly. There was a distinct crimson color in the east,—just over Copernicus Peak as seen from near the 12-inch dome.

An aurora in California,—at least in the region around San Francisco Bay,—is a very rare phenomenon, and I have no recollection of ever having seen one in this region before.

S. D. Townley.

Observed Rotations of Planetary Nebulæ.

An observation of planetary nebula NGC 7009, R. A. 20^h 58^m, Decl. — 11° 48′, secured with the three-prism Mills spectrograph on the evening of November 14, 1915, showed us, the following day, that the bright lines composing the nebular spectrum are inclined to the zero direction, as indicated by the comparison spectra of hydrogen and helium. We had made the exposure, using a slit a little longer than the east and west diameter of the nebula, for the purpose of testing the question of nebular rotation, and the inclination of lines, as described above, was the evidence which we were hoping to secure.

The general outline of the image of this nebula is elliptic with the major axis in position angle 79° and the minor axis in position angle 169°.

The first spectrogram had been secured with the telescope and spectrograph east of the pier of the telescope and the slit in position angle 90°. To make sure that the inclination of the lines was not an instrumental effect, the second spectrogram was obtained with the telescope and spectrograph west of the pier, which reverses the instrumental conditions. The slit was in position angle 79°; that is coincident with the longer axis of the nebular ellipse. The resulting spectrogram fully confirmed the results of the first observation. The third spectrogram, with telescope east of the pier and the slit in position angle 79°, was in accord with the earlier results. A fourth spectrogram, with slit in position angle 169°, that is, coincident with the minor axis of the ellipse, gave no evidence of inclination of the lines.

The ends of the lines corresponding to the west edge of the nebula are displaced to the violet with reference to the ends corresponding to the eastern edge of the nebula. The interpretation is, that the rotation of the nebula is carrying the western edge toward us and the eastern edge away from us. The maximum rotational speed appears to be at approximately 9 seconds of arc from the center of the nebula and is in amount, 6 kilometers per second. The extreme outer ends of the spectrum lines do not maintain their inclination at the full rate, but turn back slightly. This we interpret to mean that the law of rotation is such that the outer strata lag behind.

The measure of the rotational velocity should enable us, at a later date, to draw interesting conclusions as to the mass of the nebula, which seems to be many-fold that of our solar system, as to the geometric form of the nebula, whether it is an ellipse or an ellipsoid, etc.

Positive evidence of rotational effects in two other planetary nebulæ have been secured to date, as well as suspected evidence in other cases, but further announcement is delayed pending full confirmation.

W. W. Campbell,
J. H. Moore.

REVIEWS.

PUBLICATIONS OF THE CINCINNATI OBSERVATORY, No. 18.

The first part of the comprehensive catalog of proper motion stars has been issued by the University of Cincinnati. The complete catalog is to include all stars having a known proper motion of 10″ per century, or greater; but excluding the stars, mainly of the bright classes, which have been discussed for the Preliminary General Catalog of LEWIS BOSS. This first part contains the stars in the first six hours of Right Ascension, and the remainder is to be published as funds become available. As there are about seven hundred stars in this part, we may expect a list of approximately three thousand in all.

The Cincinnati Observatory, under the direction of Professor PORTER, has been distinguished for proper motion investigation, and the present catalog, compiled with the active assistance of YOWELL and SMITH, will make the most complete contribution to the subject up to date.

Nearly every important catalog of meridian circle positions has been searched for old observations, and with these have been combined the recent observations, made by Dr. ELLIOTT SMITH, with the Cincinnati instrument, four determinations of each star. The star places have been reduced to the system of AUWERS, and no corrections for magnitude equation have been introduced, since it has been assumed that such corrections would be nearly the same for the old and the recent observers, and this effect would be nearly negligible for a differential discussion of results.

The catalogs are divided, for weights, into nine classes, ranging from a weight of 0.1 to a weight of 4.0, for a single observation. The weights of the A. G. catalogs fall in the classes VI, VII, and VIII, and Albany is given one class higher than Nicolaief, which agrees with the respective errors found in those catalogs by comparison with the recent observations made here.

The Lick Observatory Catalog of Piazzi stars is classed as VIII, and the Zodiacal Catalog as IX, only seven catalogs out of one hundred and thirty being included in this highest class. In general a single observation of one class has been weighted the same as the mean of two observations of the next lower class. As many as twenty authorities have been made use of, for some of the stars, tho it is stated that when a star had been many times observed, some of the less important catalog places were not included. The deduced places, with the epochs and the respective numbers of observations, have been tabulated. The inclusion of the magnitudes would have made the present results of greater interest. These will probably be printed in the final catalog, and one can always look them up in some authority of good weight, by referring to the tabulation now published.

The Cincinnati positions are of recent date, and the prompt reduction and publication of the work will be valued by present investigators, and they are certainly very creditable to the small force of astronomers attached to the observatory.

R. H. TUCKER.

October 30, 1915.

BLACKBURNE'S TABLES.

There are many sets of tables, compiled for use in calculating a ship's position at sea, in addition to the standard works, such as *Bowditch's Navigator*, which provide the essentials, when used in combination with the Nautical Almanac. The problem in all these treatises is to give methods that can be employed without any exact knowledge of the theories involved. No study of trigonometry is required usually for the ability to calculate a ship's position, tho every detail may be said to be based upon that science; and the use of logarithms does not imply any knowledge of the construction of the logarithmic tables, to which the ship's officer constantly refers.

The tables calculated by Capt. H. S. BLACKBURNE, of New Zealand, have been designed for help in some of the problems out of the ordinary routine, as well as to illustrate the inaccuracy which results from many of the usual methods. In general they are for the purpose of combining two or more observations, made out of the meridian, and the Sun, Moon, or stars may be observed.

The usual process on a sailing ship is to get the latitude from the noon observation of the Sun, and the longitude by combination with the morning "sights." This involves, of course, a consideration of the run of the ship during the interval, which is ordinarily taken from the record of the automatic log, trailed astern. Few captains of the old style include an afternoon observation, which would add such a good check to the earlier determination.

My own remembrance of the working of a ship's position is still clear, when as a boy of fourteen, with no conception of trigonometry as yet, I learned by long practice to get the observations of the Sun, and, lying often on the cabin floor in rough weather, with the chart spread out, to follow thru the dizzy processes, and enter the correct columns of the assigned tables, and carry forward the relatively simple computations, until the pencil dot could be placed on the white chart, marking the place of the ship at noon. It was my introduction to astronomy, and it has been a pleasure since, on steamship voyages, to take up some of the details again, and amplify the methods, with some understanding of what we were driving at.

Modern steamship officers do much more thoro work; the afternoon sights of the Sun are generally obtained when possible, and it is quite usual to add the observations of the bright stars near twilight to strengthen the results.

On one voyage, running north for New York, I think we employed every method by star observation that the available books on navigation could furnish.

The chief engineer's record is also valuable to get the place by "dead reckoning," since the number of revolutions of the screw under normal conditions of loading, and of weather, gives a good check upon the distance run. Also, on a steamship, the dead reckoning is much simpler than on a sailing vessel, as the course may be run unchanged by variation in the wind. Only the force of the wind need be taken into account.

BLACKBURNE lays stress upon these extra meridian observations, and refers to three wrecks of steamers in three years that might have been avoided, had every opportunity been employed for determining the position of the ship.

A single star altitude out of the meridian can give an approximate position, when combined with the chronometer longitude. But, of course, several stars will combine to give higher precision, and the requisite checks.

In passing, it may be said that seamen are apt to expect too great accuracy for the single determination; the fact that several officers will obtain good agreement from their simultaneous observations of the Sun is misleading, since the presence of systematic errors, that may affect all the determinations, is not often recognized. The combined result may give the position of the ship within a probable error of three miles, and that should be considered fairly good work.

SUMNER's method of obtaining a position by two observations is much recommended, by the author of these tables. The practice of employing it mainly in the high latitudes, while general, could be much extended; and instances are quoted of satisfactory results in the low latitudes, by observations which were carefully chosen to give the proper "cut" for the two position lines, whose intersection gives the ship's place on the chart.

The tables include those for finding the hour-angle and azimuth from the altitude, azimuth from the altitude with latitude known, and auxiliary tables for SUMNER's method. All appear to be carefully and thoroly calculated.

The error in time and latitude, produced by assumed errors in the observations, are also discussed and tabulated. These details should be considered by navigators of the modern type, who give some thot to their work beyond the mere routine. When all is said and done, the careful captain wants a keen lookout on duty, when his calculations lead him to expect a landfall.

A pretty illustration of navigation was furnished when the Cunard ship Pannonia ran 270 miles out of her course by wireless call to rescue the Spanish steamer Balmes, on fire, northeast of the Bermudas. Each position was evidently well fixed, for the Pannonia swung off at midnight, and ran till seven the following night, when the mast-head light of the Balmes was picked up, only half a point off the course; the flare from the distressed vessel following our mast-head hail by not over a quarter of a minute. The last twilight observations had been reduced, and, actually, the slight error in these had indicated a small change of our course, which nearly accounted for the half point of deviation.

With our modern big ships, and the expertness of those who control them, every help to accurate navigation on the broad ocean will be welcomed, and sailors and landsmen should be grateful for the benefit such tables may be to the navigator.

R. H. TUCKER.

November 1, 1915.

AN INTRODUCTION TO THE STUDY OF VARIABLE STARS.[1]

In honor of the fiftieth anniversary of the founding of Vassar College, a collection of notable volumes is being published by Vassar Alumnæ. Miss FURNESS's *Introduction to the Study of Variable Stars* is one of these, and if it is typical, Vassar College has reason to be proud of the series.

The work is "the outcome of several years of teaching the subject," and its purpose and scope are well suggested by its title. It is not a comprehensive treatise such as the one now being published by Father HAGEN *(Die Veränderliche Sterne)*, but is a general introductory book (the only one published in the English language) which is suited to the needs of teachers wishing to present the subject of variable star study to a class in a practical way, and to amateurs who, without special training in astronomy, wish to make their observations of the stars of scientific value. It should also appeal to the general reader, for it contains a great amount of interesting information put into language that is clear as well as precise.

The earlier chapters of the book deal not only with the subject of stellar variation, but with a variety of other topics,—the principles of spectrum analysis, star charts and catalogs, both visual and photographic, the early history of stellar magnitude, the principles of polarized light, upon which many photometers are based, etc. The treatment of these questions is avowedly not comprehensive, but enuf is said to give the student the knowledge needed to understand the application to the subject of variable stars. Furthermore, reference is always made to books accessible in any good library wherein these matters may be studied in more detail.

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[1] By CAROLINE E. FURNESS, Ph.D., Director of the Vassar College Observatory. xv +, 327 pp., 8 vo., C2, $1.75. HOUGHTON MIFFLIN COMPANY, 1915.

The chapters dealing directly with the variable stars of different classes, the methods of their observation, the foundation of light scale, the mean light curve, the calculation of the elements, and the prediction of the maxima and minima from the elements show that Miss FURNESS is a trained observer as well as a practical and successful teacher. The treatment is full and clear and the illustrative examples are given in sufficient detail. The instructions given for the benefit of the observer naturally relate almost entirely to visual observations, made without the use of photometers, for the observer who has a Zöllner or wedge photometer, and, still more, the one equipped to carry on photographic observations may be assumed to have had special preliminary training.

The book is remarkably free from errors of any kind, practically no typographical errors and only one statement that may be misleading being found in a rather careful reading. This statement is the one on page 49 that "The southern survey of the heavens has been extended to declination —42° under the direction of Professor PERRINE at the Cordoba Observatory . . ." Of course, Dr. PERRINE, the present director, is energetically carrying on this work, but the Cordoba D. M. was planned by Dr. GOULD, and carried to —52° by the late Dr. THOME, under whose direction also the maps to —42° were issued in 1893. A new edition of these maps has recently been issued by Dr. PERRINE and this probably accounts for the slip.

R. G. AITKEN.

November 15, 1915.

GENERAL NOTES.

The Melbourne Observatory.—Private letters received at the Lick Observatory confirm the reports in the Australian papers that Mr. P. BARACCHI, State Astronomer of Victoria, resigned his position in August of the present year. It is now stated in *Nature*, on the authority of the *Age* (Melbourne), that "no successor is to be appointed, the State Government having decided to drop the work, thereby saving upwards of 4000*l* annually."

We join heartily in the hope expressed in *Nature* that "some scheme of Commonwealth control will be evolved before it is too late." It will be recalled that the Commonwealth of Australia at the time of its formation, took over the meteorological departments of all the States, but left the astronomical observatories under state control. More recently the Commonwealth Government has set aside a tract of land on Mt. Stromlo, at Canberra, the federal capital, as the site of a Commonwealth observatory, and has erected a building to shelter the 9-inch Oddie refractor (presented by the late J. ODDIE, of Adelaide). Mr. P. BARACCHI and his chief assistant, Dr. J. M. BALDWIN, have made frequent visits to Mt. Stromlo to test the suitability of the site, and their reports show that the conditions there are excellent.

We regret to record the death, on October 8, 1915, of Mr. THOMAS CAWTHRON, of Nelson, New Zealand, at the age of 82. Mr. CAWTHRON accumulated a large fortune in the shipping business, and of late years drew upon this with the greatest liberality to benefit the city of Nelson. By the terms of his will, executed in London in 1902, the greater part of his estate is left in trust for "the purchase of land and the erection and maintenance of an industrial and technical school, institute and museum to be called the Cawthron Institute." This is to be located at Nelson.

At this writing it is uncertain what effect Mr. CAWTHRON's death will have upon the plans for the Cawthron Solar Observatory, for the foundation of which he had offered a gift of £30,000. Recent advices indicate that legal difficulties were delaying the purchase of the site that had been selected and the construction to it of a suitable road. It was hoped that these difficulties would be cleared by early September, and that Mr. CAWTHRON would then sign the trust deed. If he did not do so, the fate of the solar observatory would seem to depend upon the provisions in the will for the Cawthron Institute. In this event, astronomers the world over will hope that these provisions are broad enuf to permit the trustees to carry out the admirable plans that have been made for the observatory.

R. G. A.

Another Canadian Observatory Projected.—Some time ago a project was begun by the Royal Astronomical Society of Canada with the object of securing an astronomical observatory for Toronto. It was proposed that the city provide a suitable site, the University maintain the institution and the Society use it as its headquarters and maintain its library there. The University cordially supported the scheme and the city agreed to give a splendid site in a ten-acre park. Prospects were excellent for the proposal to be carried to completion, but the breaking out of war put a temporary check to it.

However, the Society considered it wise to get sketch plans of the building drawn and to invite suggestion and criticism. These plans show a building in the shape of a T, having a 20-inch, a 9-inch and a photo-telescope at its extremities. A fine lecture hall and library as well as office and laboratory rooms are provided.

It is hoped that such an admirable project may not be too long delayed.

It is stated in *Science* that Miss MARGARET HARWOOD, who is spending the present academic year in study at the University of California, as research fellow of the Nantucket Maria Mitchell Association, has been appointed for an indefinite term, fellow of this Association and director of its observatory. Her new year at the Nantucket Observatory will begin June 15, 1916.

It is also stated that a $500.00 Maria Mitchell fellowship for research work at Harvard College Observatory will be available for the three years 1916-1919.

Science records the death, on October 17, 1915, of the Rev. Father **Charles M. Charroppin**, S. J., formerly head of the Department of Science of St. Louis University, and known especially for his astronomical work.

Rev. Father M. **Selga**, S. J., who spent the year 1914-15 at the Lick Observatory as a special student, has gone to Manila, P. I., to take charge of the astronomical department of the Manila Observatory.

It is reported that Professor **Hugo von Seeliger**, director of the Munich Observatory, has been made a Knight of the Prussian Order of Merit, and that Professor J. C. **Kapteyn**, of Groningen, Holland, has been appointed a Foreign Knight of the same order.

Nature records the death, on August 31, 1915, of Dr. **Theodor Albrecht**, chief of the International Bureau for Investigating Latitude Variation since its inception in 1898.

Spectral Classification of Stars and the Order of Stellar Evolution.—A discussion on this subject was held at the Manchester meeting of the British Association, Section A, on September 9, 1915, in which Professor **Fowler**, Sir F. W. **Dyson**, Professor **Eddington**, Father **Cortie**, Professor **Nicholson**, Mr. T. R. **Merton**, Sir **Ernest Rutherford**, and Dr. F. A. **Lindemann** participated. Their arguments, which should be read by all interested in the subject, are given in *The Observatory* for October, 1915.

President **Pickering**, of the American Astronomical Society, has appointed Professor S. D. **Townley** (Chairman), Miss **Annie** J. **Cannon**, and Professor H. N. **Russell**, to act as a committee to consider the revision of the nomenclature of variable stars. Dr. **Townley's** paper on this subject, which led to the appointing of the committee, is printed on another page of this number of the *Publications*.

The executive committee of the American Astronomical Society, on the invitation of Professor JOHN A. MILLER, has decided to hold the next meeting of the Society at Swarthmore, Penn., in August, 1916.

Small Telescope for Sale.—A Harris telescope of 2½ inches aperture, brass tube and low brass tripod, all enclosed in a wooden box, is offered for sale at $20.00 by Miss GERTRUDE H. CARLTON, 730 Nineteenth St., Oakland, Cal. Several astronomical books of popular interest are included in the offer. Such a telescope could be made very useful in the observation of variable stars.

Science each year prints a list of the doctorates conferred by American universities. In the list printed in the number for October 22, 1915, we find that seven doctorates were conferred in astronomy—three by the University of Chicago, two by the University of Michigan, and one each by the Universities of Pennsylvania and California. In the eighteen years over which the records extend, 71 doctorates have been conferred in astronomy out of a total of 3095 in all of the sciences.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, 752 PHELAN BUILDING, SAN FRANCISCO, ON SATURDAY, NOV. 27, 1915, AT 2:00 P. M.

There were present the following:—

President R. G. AITKEN and Directors CUSHING, COSTA, CORNISH, LEUSCHNER, BURCKHALTER, TOWNLEY, MARKWART and RICHARDSON.

The attention of the Board was directed to the fact that a proposition had been made to the Society by the First Federal Trust Company of San Francisco, to take from the Society its First Mortgage, 6% Gold Bond, No. 144, issued by the Moulton Irrigated Lands Company, and give therefor a new bond in equal amount and interest, together with a bonus of $10.

The matter having been investigated by the Finance Committee and favorably reported upon, a resolution was passed authorizing the Finance Committee to make the exchange. Discretion was left in the hands of the Committee either to accept a bond of the new issue of the Moulton Irrigated Lands Company, in lieu of the one now held, or to make a cash sale of Bond No. 144 at a price equal to par plus the premium offered by the First Federal Trust Company.

The following resolution was passed:—

Resolved, That the Secretary-Treasurer of this Society is hereby authorized to withdraw from the custody of the Mercantile Trust Company of San Francisco one Moulton Irrigated Lands Company 6% First Mortgage Gold Bond, No. 144, and this resolution will be the authority of the said Mercantile Trust Company to deliver the said bond, upon application, to the said Secretary-Treasurer.

The Secretary read a communication from the Second Vice-President of the Pacific Gas and Electric Company of San Francisco, inviting the Society to quote a price for its Bay Counties Power Company 5% bonds which are due September 1, 1930. The Board decided by unanimous vote that it did not care to dispose of these securities.

There being no further routine business, the Board then resolved itself into a Special Meeting for the purpose of considering the Award of the Bruce Gold Medal of the Society for the year 1916.

In addition to the nine members present, whose names are given above, Secretary RICHARDSON held the proxies of Directors W. W. CAMPBELL and WM. H. CROCKER.

Nominations were read from the six Observatories which act in an advisory capacity under the statutes which govern the award of the Bruce Medal, and a general discussion followed. A ballot was then taken which resulted in the unanimous selection of Professor GEORGE E. HALE, Director of the Mount Wilson Solar Observatory, as the Bruce Medalist for the year 1916.

Adjourned.

D. S. RICHARDSON, *Secretary.*

MINUTES OF THE REGULAR MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT CHABOT OBSERVATORY, OAKLAND, ON SATURDAY, NOVEMBER 27, 1915, AT 8:00 P. M.

After a brief statement by Mr. BURCKHALTER on the progress made in the construction of the new Chabot telescope and observatory, Mr. W. F. MEYER, Astronomer in Charge of the International Latitude Observatory at Ukiah, California, lectured on the subject: "Recent Results of the International Latitude Observatories."

Mr. MEYER, besides being an observer actively engaged in this work, has made a careful study of history of the investigations relating to the variation of terrestrial latitudes. His address gave his hearers an excellent account of the phenomena, and the laws underlying them, as well as of the methods of observation.

It is feared that the war may interfere with the coöperative plan of observation which has been in effect for the past fifteen years to such an extent as to close some or even all of the latitude stations. The Astronomical Society of the Pacific joins with astronomers generally in the hope that means may be found to prevent this unfortunate interruption to an important investigation.

D. S. RICHARDSON, *Secretary.*

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Mr. S. D. Townley	*First Vice-President*
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NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished free of cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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Rome, Italy, Specula Vaticana.
San Francisco, Cal., California Academy of Sciences.
San Francisco, Cal., Technical Society of the Pacific Coast.
Stockholm, Sweden, University Observatory.
Strassburg, Germany, Universitäts-Sternwarte.
Sydney, New South Wales, Observatory.
Tacubaya, Mexico, Observatorio Astronomico Nacional.
Tokio, Japan, University Observatory.
Toulouse, France, Observatoire.
University Park, Colorado, Chamberlin Observatory.
University of Virginia, Virginia, McCormick Observatory.
University of Pennsylvania, Upper Darby, Pa., Flower Observatory.
Upsala, Sweden, University Observatory.
Vienna, Austria, K. K. Sternwarte.
Vienna (Ottakring), Austria, Von Kuffnersche Sternwarte.
Washington, D. C., Library of Congress, Periodical Division.
Washington, D. C., National Academy of Sciences.
Washington, D. C., Naval Observatory.
Washington, D. C., Smithsonian Institution.
Washington, D. C., Nautical Almanac, U. S. Naval Office.

Washington, D. C., U. S. Coast and Geodetic Survey.
Williams Bay, Wisconsin, Yerkes Observatory.
Zurich, Switzerland, Observatory.

EXCHANGES.

Astronomische Nachrichten, Kiel, Germany.
Prof. Elis Strömgren, Observatory of Copenhagen, Denmark.
Prof. A. A. Nijland, The Observatory, Utrecht, Holland.
Prof. Dr. H. J. Klein, Editor of "Sirius," Theresien St. 85, Köln-Lindenthal, Germany.
Revista de la Sociadad Astronomica de Espana y America, Barcelona, Spain.
Mr. F. Archenhold, Director of Treptow Sternwarte, Berlin, Germany.
Mr. C. A. Chant, Royal Astronomical Society of Canada, Toronto, Canada.
Mr. F. Delporte, 76 Rue Verhulst, Eccle-Bruxellis, Belgique.
Sociedad Astronomica de Barcelona, via Diagonal 462, 2°, Barcelona, Spain.
Dr. H. Kritzinger, 40 Hindersin Str., Berlin, N. W., Germany.
Observatorio Astronomico de Cartuja, Granada, Spain.
Prof. L. Praika, Nizbor Observatory, Bohemia.
Gazette Astronomique, Société d'Astronomie d'Auvers, 29 Stamford St., London, S. E., England.
Astrophysical Journal, Williams Bay, Wisconsin.
Popular Astronomy, Northfield, Minn.
The Observatory, Greenwich, England.
Rivista di Astronomia, Società Astronomica Italiana, Turin, Italy.
Orion, Strada Rosca No. 3, Bucarest, Roumania.
Journal Astronomique, Observatoire de Lille, Hem, France.
Astronomia Popolare, Palazo Madama, Turin, Italy.
Società Astronomica Italiana, Rue Maria Vittoria 23, Turin, Italy.
The Journal of the British Astronomical Association, care F. W. Levander, 30 North Villas, Camden Square, N. W., London, England
Monthly Notices, Royal Astronomical Society, London, England.
American Mathematical Society, 501 West 116th St., New York, N. Y.
Società degli Spettroscopisti Italiani, Catania, Italy.
Sociedad Cientifica "Antonio Alzate," Mexico, Mexico.
Solar Observatory, Mount Wilson, via Pasadena, Cal.
American Philosophical Society, 105 South Fifth St., Philadelphia, Pa.
Harvard College Observatory, Cambridge, Mass.
The Monthly Evening Star Map, 150 Nassau St., New York, N. Y.
The Astronomical Herald, Tokyo, Japan.
Publication of Pomona College, Claremont, Cal.
The Astronomical Journal, Dudley Observatory, Albany, N. Y.
Journal de Physique, 5 Rue de la Santé (13^e), Paris, France.
Journal of the Royal Astronomical Society of Canada, 198 College St., Toronto, Canada.
Ciel et Terre, 24 Avenue des Villas, Bruxelles, Belgium.
Library Weather Bureau, Washington, D. C.

ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY IN AWARDING THE BRUCE GOLD MEDAL TO DR. GEORGE ELLERY HALE.

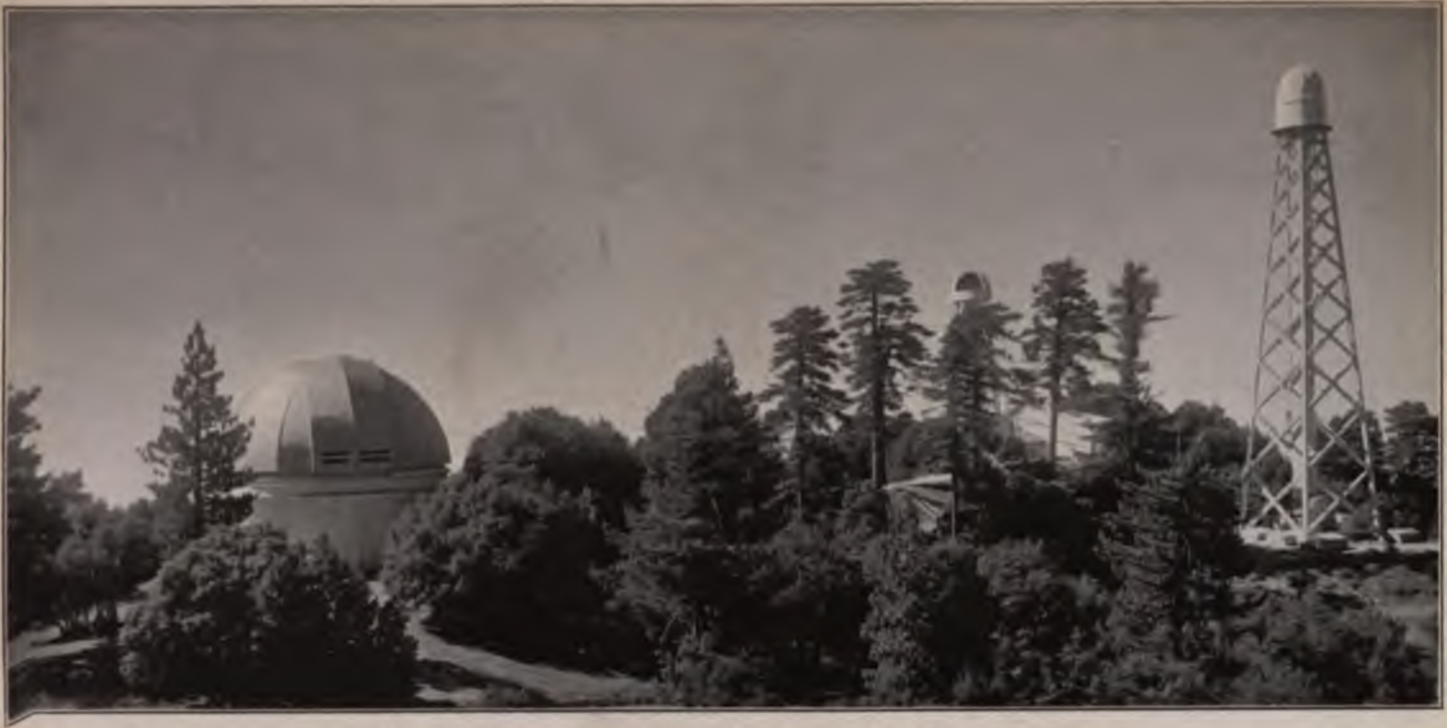
By Robert G. Aitken.

It is my privilege this evening as well as my duty to make the formal announcement of the award of the Bruce Gold Medal of our Society for the year 1916 to Dr. George Ellery Hale, the Director of the Mount Wilson Solar Observatory of the Carnegie Institution of Washington, and to state the grounds upon which the award has been made.

The Bruce Medal is international in character and is given for "distinguished services to astronomy" in any field. Among the twelve previous recipients of the award, we find four American, two English, and two German astronomers, and one representative each of Italy, France, Holland and Russia. In the list are men whose reputation rests entirely upon theoretical research; others whose preëminence is mainly due to observational work; some represent astronomy in Bessel's definition of the word, others are pioneers in what Langley called the "New Astronomy"; some have confined their attention chiefly to our solar system, others to the systems of the stars. Our present medalist is an American, a citizen of our own State, and a representative of the new astronomy, but he differs from all our earlier medalists in his chief subject of study, which has been and is the central body of our system, the Sun itself.

For fully twenty years Mr. Hale has been a professional astronomer, the organizer, builder and director of two of the great observatories of the world, but, by his own definition, he is still as truly an amateur as he was when he made his first astronomical observations in a room in his father's house in Chicago with instruments largely of his own design and construction. Hear his definition of the term!—"According to my view, the amateur is the man who works in astronomy because he cannot help it, because he would rather do such work than anything else in the world, and who therefore cares little for hampering traditions or for difficulties of any kind."

We should expect the man who wrote these words to be



View from the Balcony of the Dome of the 100-Inch Telescope.

characterized by an intense enthusiasm for research, and by the optimism necessary to carry him thru almost any discouragement, and this, indeed, is the fact. The fountain-head of these qualities must naturally lie in Mr. HALE's own nature, but he owes much to the fortunate environment of his early youth. His father, the late WILLIAM ELLERY HALE, to whom our medalist is, as he himself tells us, indebted beyond measure, fostered the boy's early love for natural science, was interested in his simple physical and chemical experiments, his observations of infusoria, his photographs of various objects with a microscope. He encouraged the boy to use tools and to build instruments of his own before buying better ones for him, and thus stimulated his enterprise, his self-reliance and his resourcefulness. In view of this early history it is less surprising to find our medalist as a boy of fifteen photographing the partial eclipse of the Sun in 1883, and to learn that even then he was passionately devoted to spectroscopy.

It was five years later, when he was a student at the Massachusetts Institute of Technology, that Mr. HALE designed a small brick building at his father's home at Kenwood to contain a ten-foot Rowland concave grating, with shop, laboratory and dark-room and thus began his active career as a builder of observatories and as an investigator of solar phenomena and of the problem of stellar evolution along the lines he has consistently followed in all his later work. Note that this first spectrograph was an instrument of *high dispersion* and that this first observatory made provision not only for a spectrograph, but also for a shop and a laboratory. Mr. HALE has from the beginning demanded powerful instruments, tho not necessarily expensive ones, and he has insisted upon shops and laboratories as indispensable adjuncts to an observatory.

In 1889, when he was but twenty-one years old, the principle of the spectroheliograph [1] occurred to him and with a simply nstructed instrument he began his experiments at the Harvard College Observatory thru the kindness of Professor Pickering. These early attempts were not successful, but three years later he had added a 12-inch refractor to the equipment of the Kenwood Observatory and in a photographic study of the spectrum of the solar chromosphere and prominences had observed the two brilliant lines due to calcium vapor in the Sun's atmosphere which are known as the H and K lines. Lying in the violet end of the visual spectrum, close to the limit of wave length to which the eye is sensitive, these lines had almost escaped notice in the visual studies of the Sun tho they had been seen by C. A. Young. This short wavelength region of the spectrum, however, strongly affects the ordinary photographic plate, hence on the photographs the H and K lines are, as I have said, brilliant. Moreover they appear in the solar spectrum, superposed upon "broad dark bands which greatly diminish the brightness of the sky spectrum" and are therefore admirably adapted to the spectroheliograph.

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[1] The light of the Sun admitted into the narrow slit of an ordinary spectrograph and passed thru its train of lenses and prisms is spread out into a long band of color crossed by lines representing various chemical elements. Such a "spectrum" can be recorded on a photographic plate. Suppose that immediately in front of this plate an opaque diaphram is placed with a narrow slit in it to correspond precisely to the position of one of the spectral lines. Obviously light from this line and from no other portion of the spectrum will be recorded on the plate. Now provide a mechanism to move the entire spectrograph (including the diaphram with the second slit), with respect to the solar image and the photographic plate. A complete picture of the Sun, in the light of this one spectral line, will be built up on the plate. The instrument is now a spectroheliograph.

The difficulties that had prevented earlier success with this instrument were now quickly surmounted, and early in February, 1892, Mr. Hale obtained fairly good images of the Sun in the light of the H and K spectral lines A new and powerful instrument of fundamental importance in the study of solar phenomena was thus placed at the service of astronomy and Mr. Hale at once took a prominent place among the astronomers of the world.

It is probable that no one has ever made a discovery or invention of importance that had not been to some degree anticipated by others. It would be easy to cite numerous examples to support this statement. In the case of the spectroheliograph, the principle involved had been stated, essentially, by Janssen as early as 1869, an instrument had been designed by Braun, at Kalocsa, in 1872, but not built for lack of funds, and experiments with a spectroheliograph were actually carried out by Lohse, at Potsdam, in 1880. They were unsuccessful, however, and Lohse did not continue them. These facts in no wise detract from the merit of Mr. Hale's work, for he thot out the principle on which the instrument is based quite independently, and, what is of more importance, *he continued his experiments until he had achieved success.* The spectroheliograph is therefore justly regarded as his invention.

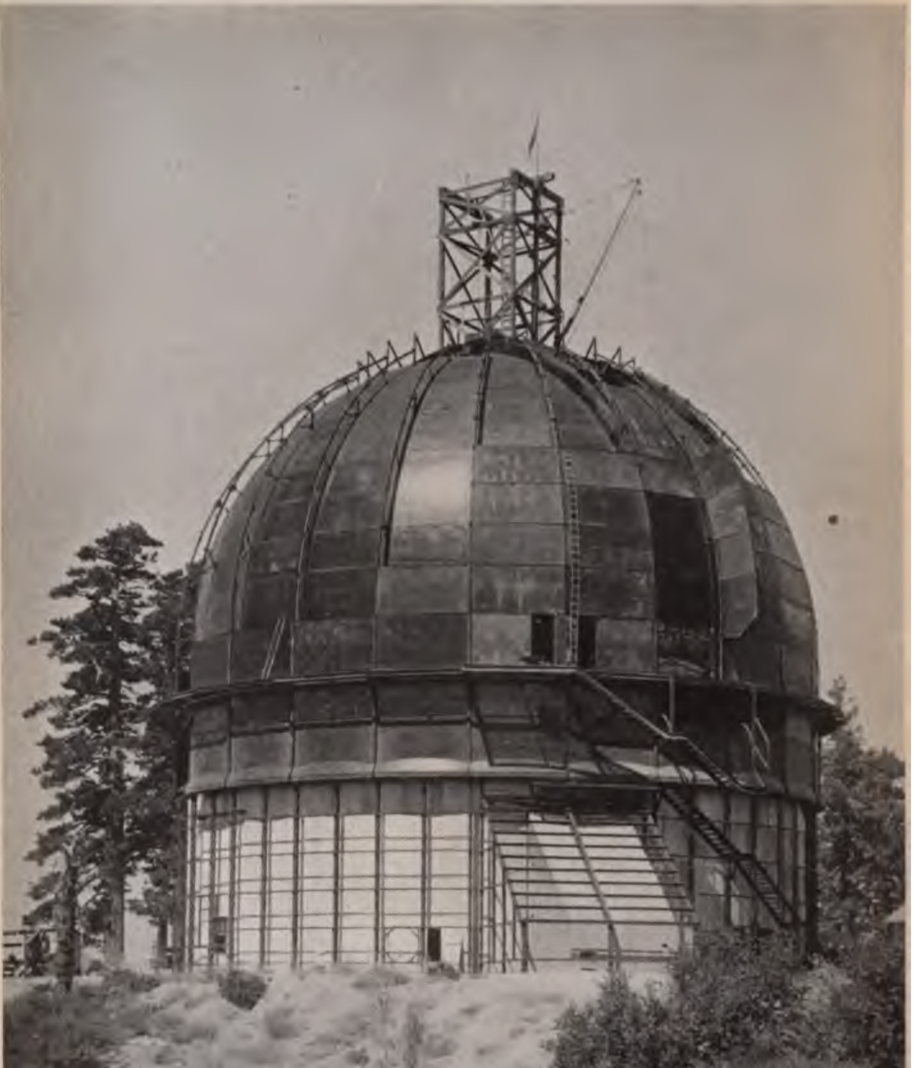
It is not my purpose to-night to dwell at length upon our medalist's multifarious activities as director first of the Yerkes, then of the Solar Observatory, as founder and editor of the *Astrophysical Journal*, as the man chiefly responsible for the organization of the International Union for Coöperation in Solar Research, but I do want to show you that all of these activities have been but the logical development, the evolution, if you please, of his original working program.

At the beginning of his work, Mr. HALE realized that the Sun is only a star, differing in no essential from thousands of the stars visible to the eye and to the telescope, except that it is placed near enuf to present to us a large disk instead of a point image, and thus to permit us to study its phenomena in detail. This is an obvious truth to us now, and was, indeed, no new idea a quarter century ago, but its implications and its opportunities had been so generally overlooked and neglected that Mr. HALE's revival of it held almost the novelty of a discovery. The Sun, then, as the "unique means of opening to us a knowledge of stellar development," held the central place in his scheme of research. That his conception of the problem of stellar evolution has grown and broadened as increasing knowledge and experience have brought an ever wider vision it is hardly needful to say, but it is apparent from his earliest writings and from the equipment of his observatory at Kenwood that he *began* his work with a firm grasp upon the conditions of the problem and a clearly outlined plan of attack upon it. The Sun was to furnish the key to decipher the mysteries hidden in stellar spectra, carefully chosen laboratory experiments were to guide in the interpretation of the observed solar phenomena, and the study of the stars and of the nebulæ in their relation to the Sun and to each other was to form the third of these converging lines of attack.

It is obvious that the full development of such a comprehensive program of work lies beyond the powers of any individual or even of any one institution, however well equipped. Every possible method of study and practically every form of telescope must be employed. Visual observations, with telescopes large and small, photographic observations, spectrographic observations, all have their particular functions. Moreover the student of stellar evolution must be alert to avail himself of every advance made in other fields of science, by the physicist, the chemist, and the engineer. He must constantly devise new instruments, new methods of attack, to apply these advances to his own problems. Finally, the Sun must be kept under continuous observation, not only from day to day, but from hour to hour, for prominences arise, reach their full development and vanish sometimes in the fraction of an hour; sunspots come and go on no regular schedule; faculæ and flocculi are as capricious in their changes as the clouds and air currents in our own atmosphere.

We find Mr. HALE, therefore, insisting upon the need of a large number of investigators "working, if possible, on some coöperative plan, at many stations widely separated in longitude." Intelligent coöperation is conditioned upon organization and upon convenient media of intercommunication. Recognition of these conditions led Mr. HALE to advocate as early as 1892, the foundation of an astrophysical journal, to undertake the editorial responsibility when it was established, and to take the initiative in the formation of the International Union for Coöperation in Solar Research, which held its first meeting in September, 1904. This admirable Union now includes practically every student of solar physics in the world and its organization is so skillfully planned that while it provides for thoro systematization and coöperation it leaves the initiative of every member full play, and, indeed, stimulates each one to original research.

It is but the further development of these ideas that has led Mr. HALE in more recent years to take such an active part in the work of the National Academy of Sciences, to emphasize the importance of National Academies as forums for the free interchange of thot by men engaged in different lines of research, and to establish, with his brother and sister, the *William Ellery Hale Lectures on Evolution*, for he regards "all natural phenomena as elements in a single problem," and believes, as Sir WILLIAM HUGGINS phrases it, that "through



DOME FOR 100-INCH TELESCOPE, SEPTEMBER, 1915.

all the ages the Cosmos has advanced, and is still advancing, by a process of orderly evolution."

"The power of focussing simultaneously the wider view and the minute observation," says SCHUSTER, "is perhaps the most characteristic attribute of those who reach the highest eminence in any profession."

Mr. HALE possesses this power in a marked degree. The wider view has been emphasized in what I have been saying, but his personal research work has been characterized no less by minute and accurate observation. Without attempting to describe this work in detail, let me rapidly pass in review some of its more important features.

At Kenwood, the spectroheliograph was employed diligently until May, 1895, and a great variety of solar phenomena were recorded on the 3000 photographs secured. It was demonstrated that the spectroheliograph "provided a simple and accurate means of photographing the solar prominences in full sunlight," and that it revealed and recorded an entirely new class of phenomena, inaccessible to any other instrument. I refer to the enormous gas clouds in the Sun's atmosphere which Mr. HALE has named "flocculi"; for the photographs taken in the light of the H and K lines recorded the distribution of calcium vapor *above the Sun's disk* as well as in the prominences at its limb. The bright H and K lines are peculiarly adapted to spectroheliographic investigations, but it was apparent that with suitable instruments other spectral lines could be utilized and the distribution of other gases in the Sun's atmosphere studied. An instrument of higher dispersion was demanded for this, and to study the finer details of even the calcium flocculi an image of the Sun much larger than the 2-inch image formed by the 12-inch Kenwood refractor was needed.

Fortunately, in 1893, the opportunity to secure a refractor of the largest size presented itself, for by a combination of circumstances unnecessary to detail here, disks of glass of the highest quality, suitable for the construction of a 40-inch lens, were for sale. Mr. HALE interested President HARPER of the University of Chicago in the project, and the latter finally secured from Mr. C. T. YERKES of Chicago the funds for building the telescope and a suitable observatory. Naturally enuf, our medalist was called upon to build the new institution and to direct its work, and altho he realized the inevitable interruption to his personal researches involved, he recognized also the command to larger service for the common good and cheerfully shouldered the heavy responsibilities. The construction of the Yerkes Observatory was begun in 1895 and completed in 1897, and the new institution promptly took rank among the great observatories of the world, not only by reason of its powerful equipment, but even more because of the high quality of the work done by its staff. The wisdom of Mr. HALE's decision to base the scheme of work of the Yerkes Observatory "on a deliberate intention to realize the fullest possible advantages of the 40-inch refractor in the diverse researches for which it is peculiarly adapted" has been fully demonstrated.

Many of these researches are, in the nature of the case, not intimately related to each other or to the problem of stellar evolution, in which Mr. HALE's chief interest lies. The working program, however, provided for the study of this problem and it was Mr. HALE's hope that he could continue his spectroheliographic work without delay. Unfortunately, as is too often the case, there was no endowment fund for the new observatory, and the difficulty of finding funds for instruments supplementary to the great refractor and for the prosecution of the observatory work not only imposed heavy burdens upon our medalist, in his capacity as Director, but prevented the construction of a suitable spectroheliograph until 1898. The Rumford spectroheliograph then built was specially adapted to the 40-inch telescope, and the second slit was so designed that it could be used with any line in the solar spectrum and not merely with the bright H and K lines. With this instrument Mr. HALE succeeded, in May, 1903, in securing for the first time photographs of the Sun's image in light of the dark hydrogen lines, thus bringing the distribution of this gas in the solar atmosphere within the range of investigation. A far more striking achievement, one that savors of the miraculous, was the photographing of sections of the calcium flocculi at different heights above the photosphere of the Sun. This was accomplished by utilizing the "simple means first described by M. Deslandres."

"At the base of the flocculi," writes Mr. Hale, "the calcium vapor, just rising from the Sun's interior, is comparatively dense. As it passes upward thru the flocculi it reaches a region of much lower pressure, and during the ascent it might be expected to expand, and therefore to become less dense. Now we know from experiments in the laboratory that dense calcium vapor produces very broad spectral bands, and that, as the density of the vapor is decreased, these bands narrow down into fine, sharp lines. An examination of the solar spectrum will show that the H and K lines of calcium give evidence of the occurrence of this substance under widely different densities in the Sun. The broad dark bands, which for our convenience we designate H_1 and K_1, are due to the low-lying, dense calcium vapor. At their middle points (over flocculi) are seen two bright lines, which are much narrower and better defined. These lines, designated H_2 and K_2, are the ones ordinarily employed in photographing the flocculi with the spectroheliograph. Superposed upon these bright lines are still narrower dark lines, due to the absorption of cooler calcium vapor at higher elevations (H_3, K_3). It will be seen that the evidence of the existence of calcium vapor at various densities in the Sun is apparently complete, and that we may here find a way of photographing the vapor at low levels without admitting to the photographic plate any light that comes from the rarer vapors at higher levels. It is simply necessary to set the second slit of the spectroheliograph near the edge of the broad H_1 or K_1 bands in order to obtain a picture showing only that vapor which is dense enuf to produce a band of width sufficient to reach this position of the slit. No light from the rarer vapors above can enter the second slit under these circumstances, since they are incapable of producing a band of the necessary width."[1]

The great sun-spot of October, 1903, offered the opportunity for testing the new method and the results were completely successful. It is a temptation to describe the differences in the structure of the hydrogen and calcium flocculi and the variations in the latter with their level in the solar atmosphere, and to discuss their bearings upon our theories of the forces at work in the Sun. Time, however, is lacking and it must suffice to say that Mr. HALE has developed these points in various papers reporting the progress of his investigations.

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[1] *The Study of Stellar Evolution*, p. 90.

For the same reason we must pass over the other work done at the Yerkes Observatory, with merely the briefest reference to the research on the Spectra of Stars of SECCHI's Fourth Type—the so-called carbon stars--which was undertaken in January, 1898, with the assistance of ELLERMAN and PARKHURST, and which affords an admirable illustration of the "combined attack" method in studying astronomical problems. "In conjunction with this investigation," says Mr. HALE, "photographs have been made of the spectra of a number of stars of other types, researches on the condition of carbon in the solar chromosphere and on the widened lines in sun-spots have been set on foot, and considerable work on the spectrum of carbon and other substances has been done in the laboratory."

Exceedingly valuable work in solar research has been, and is being done with the Rumford spectroheliograph, but Mr. HALE recognized the promising opportunity that remained to apply instruments of higher dispersion "to the investigation of sun-spots, the chromosphere, and other details of a large solar image." Such instruments are too long to be attached to a moving telescope and "it became necessary to develop a suitable form of fixed telescope," which could be made to bring a large scale image of the Sun to a focus at the slit of a powerful spectroscope or spectroheliograph mounted on fixed supports. A beginning in this direction was made by the construction of the Snow horizontal telescope at the Yerkes Observatory. "It consists of a coelostat, with a plane mirror 30 inches in diameter, rotated by clock work at such a rate as to keep the beam of sunlight, reflected from its silvered (front) surface, in a fixed position on a second plane mirror standing above and south of it. From this mirror the beam is reflected nearly horizontally to a point 100 feet north, where it falls on a 24-inch concave mirror of 60-feet focal length, which forms a solar image about six and one-half inches in diameter on the slit of a spectroscope or spectroheliograph."

Before work with this telescope had passed the experimental stage an appropriation was secured from the newly established Carnegie Institution of Washington to take it (in 1904) to Mount Wilson in California, where preliminary tests had shown that the conditions were unusually favorable for solar observation. The results secured were entirely satisfactory and doubtless formed a large factor in the decision of the Carnegie Institution to establish a solar observatory on this site. To our medalist was again entrusted the responsibility of planning, and directing a great observatory—an observatory this time, whose prime object it is "to apply new instruments and methods of research in a study of the physical elements of the problem of stellar evolution," with special attention to solar physics.

Experiments in photographing the Sun from a station in a tall pine tree on Mount Wilson convinced Mr. HALE that it would be a great advantage to mount a coelostat high enuf to avoid the disturbed image due to ground radiations. Accordingly a telescope of entirely novel type, the "tower telescope," was designed. A simple "windmill tower" was erected, supporting a platform, about 65 feet above the ground, on which the coelostat and second mirror were so mounted as to send the beam of sunlight vertically downward thru a 60-foot-focus lens which formed an image of the Sun just above the ground. Here it fell upon the slit of a spectroscope or spectroheliograph which was placed at the bottom of a "well" 30 feet deep, where the temperature remained almost constant and where there was no vibration. The success achieved with the 60-foot tower telescope has more recently led to the construction of another, with a tower 150 feet high, and well 75 feet deep, which forms a solar image nearly 17 inches in diameter.

Another powerful instrument at Mount Wilson is the 60-inch reflecting telescope, the mirror for which had been partly completed at the Yerkes Observatory. It is not used for solar work, but for observations on stars and nebulæ, designed "to throw light on the past and future condition of the Sun." This magnificent instrument is the most powerful one of its type in actual use, but one even larger, with a mirror 100 inches in diameter, is nearly completed, and may be in operation by 1917.

The Snow telescope, the two tower telescopes, and the two giant reflectors, with their accessories on Mount Wilson, and the splendid laboratories and shops at Pasadena, constitute a well-nigh ideal equipment for that combined attack upon the problem of stellar evolution which has from the first been Mr. Hale's ambition. That marvelous advances in our knowledge will result is attested by the work already accomplished, partial accounts of which are published in the four volumes of "Contributions from the Mount Wilson Solar Observatory." Here we find spectrographic studies of the Sun's disk at the center and near the limb; of sun-spots, prominences, and the "reversing layer"; of stars, nebulæ, and the Milky Way; of iron, titanium and other elements made in the laboratory under varying conditions of temperature and pressure and under the influence of a magnetic field; also spectroheliographic studies of prominences, sun-spots and flocculi, and scores of other researches—all related to some phase of the one great problem.

It was in 1908 that a staining method devised by Wallace for making photographic plates sensitive to red light, enabled Mr. Hale to use the Hα line of hydrogen in his spectroheliographic studies. It had been practically demonstrated at the Yerkes Observatory as early as 1903 that the hydrogen vapor which produces the Hβ, Hγ and Hδ lines in the spectrum of the prominences, and which forms the hydrogen flocculi lies at higher levels in the Sun's atmosphere than does the calcium vapor responsible for the H_2 and K_2 lines. Indeed, even then Mr. Hale stated that the strongest hydrogen flocculi were probably "prominences" seen in projection upon the Sun's disk. Evidence was also found which favored the belief that the Hα line in the red end of the spectrum came from hydrogen at still higher levels. The spectroheliograms made with this line early in 1908 raised this conclusion from an assumption to a demonstrable fact, confirmed the earlier hypothesis that many of the flocculi were prominences in projection on the disk,[1] and, further, clearly revealed a "vortex" structure in the atmosphere above the sun-spots.

It is this vortex structure that has chiefly engaged Mr.

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[1] Recent photographs with the new 13-foot spectroheliograph have proved this more conclusively, and Evershed and Ricco have reached the same conclusion from their researches.

HALE's attention in the researches his health has permitted in the past seven years—and the remarkable discoveries he has made and the conclusions to which he has been led form one of the brilliant chapters in the history of solar research.

The theory that sun-spots are in some manner the manifestations of cyclones or vortices in the Sun's atmosphere is, of course, no new one. It is the *proof* that is new. New, too, is the development from these observations that sun-spots are the centers of magnetic fields. This was suggested by Mr. HALE in his first paper on "Solar Vortices," which also pointed out the methods to use in testing the hypothesis. Here, again, he shows his alertness to utilize every advance made by workers in other fields, for it was by showing that the spectra of sun-spots exhibit the doubling and tripling of lines and the polarization phenomena which ZEEMAN in his laboratory researches had proved to be the distinguishing characteristics of the spectrum of a light source placed in a magnetic field that Mr. HALE was able to confirm his hyphothesis. To pass from this to the attempt to detect the presence of a general magnetic field in the Sun was to him the natural next step. Even to men so skilled in experimentation, so resourceful in devising new methods and so well equipped with powerful apparatus as are our medalist and his colleagues, this research presents extraordinary difficulties. Nevertheless, success is crowning their efforts, and it has been proven that the Sun, like the Earth, is a great magnet. The latest results even give a value for the inclination of the Sun's magnetic axis to the axis of rotation and indicate that the former axis revolves about the latter in a very short period.

Mr. HALE subscribes to HERSCHEL's dictum that "to draw not only certain conclusions, but also conjectural views" from observations is "the very end for which only observations ought to be made." He is very careful, however, to discriminate between apparently certain conclusions and purely conjectural views in which, as he says, "we must be constantly on our guard against specious resemblances." Always, moreover, he takes pains to point out the lines and methods of research that provide critical tests for his hypotheses, and, like every true man of science, he stands ready to abandon even his most cherished theories when new evidence turns against them.

It has been my object to show that "continuity of purpose and a definite scheme of research, bringing a variety of methods to bear upon a common end," have been the distinguishing characteristics of all of our medalist's work. I need hardly apologize for omitting even the mention of many of his important contributions to knowledge, for as long ago as 1904, in his address in awarding Mr. HALE the Gold Medal of the Royal Astronomical Society, Professor TURNER said that "to attempt to follow the activities of such a man during a dozen years in the space allotted to this address would be merely bewildering." What would it be now after eleven additional years of activity! It is enuf if, in my incomplete and very imperfect sketch, I have shown that our medalist has indeed rendered "distinguished services to astronomy."

He would not have me close, however, without definitely pointing out that he has not been the only successful worker in solar research in the past quarter century. He would, I am sure, wish me to remind you that Mr. EVERSHED, in England, began work with the spectroheliograph within a few months, and M. DESLANDRES, in France, about a year after the time when his own first success was achieved, and that they and many others have been most active in extending our knowledge of the complicated phenomena of the Sun. Nor would he have me fail to remind you of the value of these researches to him in his own work, and of the great assistance rendered by his colleagues (especially by ELLERMAN, who was with him at the Kenwood as well as the Yerkes Observatory, and who was the first to go with him to Mount Wilson), for he has ever been the first to recognize the merits of any research by others and to acknowledge his own indebtedness to others. In his letter accepting the award of the Bruce Medal he writes that "credit for the work of both the Mount Wilson and the Yerkes Observatories is due in very large degree to my present and former colleagues," and in a later personal letter he reiterates this statement. In the latter he also voices his hope never to leave the work at Mount Wilson, and says "my one desire is for an opportunity to push forward my investigations with effective instrumental means."

Mr. HALE, in consequence of conditions brought about by the European war, the Bruce Gold Medal ordered for you from the Paris Mint has not yet reached us. I therefore hand you this bronze replica in token of the award, the highest honor within the gift of our Society.

We all join in the earnest hope that long years of health and strength may be granted you to improve the splendid opportunity which lies before you and which you yourself have done so much to create.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1916.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon . .	Mar.	3,	$7^h\ 58^m$ P.M.	New Moon . . .	Apr.	2,	$8^h\ 21^m$ A.M.
First Quarter	"	11,	10 33 A.M.	First Quarter .	"	10,	6 36 A.M.
Full Moon . .	"	19,	9 27 A.M.	Full Moon	"	17,	9 7 P.M.
Last Quarter	"	26,	8 22 A.M.	Last Quarter . .	"	24,	2 38 P.M.

The vernal equinox, the time when the Sun crosses the celestial equator from south to north, occurs March 20, $2^h\ 47^m$ P. M., Pacific Time. As the tropical year is about six hours longer than 365 days, the equinox in 1917 will come about six hours later; the same phenomenon will be repeated in 1918 and 1919, but in 1920, the next leap year, with the extra day, February 29, the time of equinox will drop back to nearly the time for the present year. As 1900 was not a leap year the date of the equinox during the latter part of the last century was about one day earlier than it now is.

Mercury is a morning star, reaching its greatest western elongation, 27° 6′, on March 1. It then rises about an hour and ten minutes before sunrise and may be seen in the early morning twilight if the atmospheric conditions are good. The elongation is considerably greater than the average, as it occurs only eight days before aphelion. The occasions for naked-eye visibility of *Mercury* as a morning star during the winter months are not common. After greatest west elongation the apparent distance between planet and Sun gradually diminishes until superior conjunction is reached on April 14. The planet then becomes an evening star and moves eastward and northward relative to the Sun rather rapidly, so that by the end of the month it remains above the horizon considerably more than an hour after sunset, and it will be an easy object to see in the evening twilight. This condition will continue during the greater part of May. *Mercury* and *Uranus* are in very close conjunction March 4, 5 P. M., Pacific Time, the former being only 8′ south of the latter. It will then be full daylight in the

United States, but they will still be quite close together on the following morning.

Venus is an evening star thruout March and April, in a very favorable position for observation, being above the horizon more than three hours after sunset on March 1, and this interval is increased to almost four hours by the end of April. The apparent distance between planet and Sun gradually increases until April 24, when the planet reaches greatest east elongation, 45° 39′. The planet will then set a trifle more than four hours after sunset, an unusually long interval, due to the combination of greatest elongation with a position considerably north of the Sun. This last is notably enhanced by the circumstance that *Venus* has just passed its "greatest heliocentric north latitude," that is, it is in that part of its orbit farthest above the Earth's orbit. During the two months' period the motion of the planet is 67° eastward and 19° northward from the eastern part of *Pisces* thru *Aries* to the eastern part of *Taurus*. During the early days of April it passes a little south of the *Pleiades*.

Mars has begun to lose the brightness which it had at opposition in February, but is still quite conspicuous and remains in good position for observation. On March 1 it sets a little before sunrise Its setting time comes earlier and earlier each day, but the change is small, so that by the end of April it remains above the horizon until nearly 2 A. M. Up to March 22 its motion among the stars is slowly westward, about 3°. It then begins to move eastward, so that by the end of April it will have moved a little more than 7°. Its eastward path is south of the westward, and on April 30 it will be about 2° 30′ south of the position it held on February 16. It moves from the constellation *Cancer* into *Leo*, and at the end of April is about 8° west and north of *Regulus*, the principal star of the constellation. From the first of March, when its brightness is only a little less than it was at opposition, up to the end of April its brightness diminishes nearly one and one-half magnitudes; but even at the latter date it will still be nearly twice as bright as *Regulus*, the first magnitude star near it. Its distance from the Earth increases from 67 to 110 millions of miles during the two months. On April 10 its distance from us is equal to the Earth's mean distance from the Sun. The planet reaches its aphelion, the greatest distance from the Sun, on March 3.

Jupiter on March 1 sets not quite two hours after sunset, but the more rapid apparent eastward motion of the Sun among the stars causes the distance between planet and Sun to diminish rapidly and conjunction occurs on April 1. As *Jupiter* is in the part of its orbit farthest south from the plane of the Earth's orbit, the planet will not pass behind the Sun, but about 1° to the south. *Jupiter* will now be a morning star and apparently recede from the Sun, but will also be several degrees south of the Sun, so that the interval between the rising of the planet and sunrise will increase rather slowly, being less than one hour on April 30, and the planet will not be an easy naked-eye object until well into May.

Saturn remains in good position for evening view thru March and April. It does not set until about three hours before sunrise on March 1. It sets about four minutes earlier daily, until by the end of April its setting time is about half an hour before midnight. Until March 11 its motion is westward in the constellation *Gemini*. It then resumes its eastward motion and by the end of April it is in nearly the same position it occupied at the end of January. It lies several degrees south and west of *Castor* and *Pollux*, the principal stars of the constellation *Gemini*. The appearance of the rings is about the same as in January.

Uranus is a morning star, rising about $5^h\ 40^m$ A. M. on March 1, and four hours earlier on April 30. It is not in a very good position for identification, being in rather a barren region on the border line between *Capricorn* and *Aquarius*.

Neptune is in the evening sky in the constellation *Cancer*, but cannot be seen without the aid of a telescope.

NOTES FROM PACIFIC COAST OBSERVATORIES.

FORMULÆ FOR SPECTROSCOPIC BINARY ORBITS OF SMALL ECCENTRICITY AND FOR SYSTEMS SHOWING TWO SPECTRA.

In the determination of nearly circular spectroscopic orbits the usual graphic and differential formulæ become difficult of application for the evaluation of the small eccentricity and the angle of periastron. The present paper contains new adaptations of the differential and analytic formulæ for use in the case of small eccentricity. Moreover, for the case when two spectra are visible so that measures of velocity of both component masses are available, a new combination of formulæ is suggested for the purpose of employing both velocities and for the derivation of a consistent system of elements of the component orbits.

From the two equations representing the velocity in the line of sight of the two masses respectively of a binary system are derived: first, the equation containing as unknowns the radial velocity of the center of mass and the ratio of masses; second, the equation containing the orbital elements. The first equation and the differential of the second have been adapted to convenient application and computation and into both may be entered simultaneously the measured velocities of both component masses. The resulting series of equations are to be solved by least squares for the quantities mentioned. For the case of very small eccentricity, the second equation has been developed analytically into a particular form of Fourier series in terms of the small eccentricity and multiples of a phase angle reckoned from an arbitrary epoch. An endeavor has been made to include all second order terms, but the result shows that only part of these may be retained in a least squares solution. Special adaptations for convenient computation have been introduced. The total result is a form of rigorous solution by least squares for the eccentricity and the angle of periastron without a preliminary assumption of their values.

The developments here given were suggested by the problem presented by the spectroscopic binary v_4 *Eridani*, which shows two spectra the measures of which indicate nearly circular orbital motion. Altho the method requires more than usual accuracy in the observed velocities, it has been applied to this binary system for the purpose of illustration. The results together with a discussion of the physical constants of the system are given in the following paper.

This paper has been published in full in Lick Observatory Bulletin, No. 274. G. F. PADDOCK.

THE SPECTROSCOPIC BINARY v_4 ERIDANI.

The binary system of v_4 *Eridani* gives two equally bright spectra of Class B9. The hydrogen line Hγ at 4340A is strong and broad and not always measurable. The magnesium line at 4481 A is strong and fairly well defined. Many faint lines are visible on those plates on which the two spectra are coincident. From one of these plates the wave-lengths and identification of 40 lines were determined, showing that the spectrum contains besides hydrogen the enhanced lines of iron, titanium, manganese, chromium, and magnesium. The spectrum is essentially Sirian.

Of the 61 plates obtained of this binary, 39 showed the two magnesium lines at 4481 A distinctly separated. The measures of these alone were used for the solution of the orbit, which was obviously nearly circular. For the derivation of the small eccentricity and nearly indeterminate angle of periastron, the analytic formulæ of the preceding paper were employed. The circumstance that the observed velocities were not sufficiently accurate for the application of these formulæ was set aside in order to illustrate the methods. Two least squares solutions were performed, one for the velocity of the system and ratio of the masses, and one for the orbital elements, with the result that the elements are given for the system and for each component mass on a consistent basis. A comparison of these elements with those of other binary systems shows that this system is one of average and normal values.

The star is not far from the Antapex of the Sun's motion and the observed velocity of the system is practically that due to the solar motion. The density is not improbably low like that of the eclipsing systems. The parallax is unknown, but on the basis of PLUMMER's hypothetical parallaxes for Class A stars, τ_4 *Eridani* has a parallax of 0."03 and is one of a star group of similar spectral class and similar motions. On the basis of a probable orbital inclination, low density, and the hypothetical parallax, the physical system of τ_4 *Eridani* may be thus described: The component masses are somewhat less massive but slightly larger than the Sun, having an intrinsic luminosity at least eight times that of the Sun and a total luminosity of probably not less than thirty times that of the Sun.

The principal elements are:—

$P = 5.010$ days
$v = -17.8^{km}$
$\left.\begin{matrix} m_2 \\ m_1 \end{matrix}\right\} = 0.9832$
$e = 0.01 \pm$
$K_1 = 63.8^{km}$
$k_2 = 64.8^{km}$
$(a_1 + a_2) \sin i = 8800000^{km}$

This paper has been published in full in Lick Observatory Bulletin, No. 274. G. F. PADDOCK.

NEW LIGHT ELEMENTS AND REVISED ORBIT OF UZ CYGNI.

The publication, in the second part of Volume **69** of the *Harvard Annals*, of more than 3000 observations of eclipsing variable stars permits the revision of many of the orbits published by the writer a year ago.[1] The observations, which were made during the years 1903 to 1912 by Professor WENDELL with a sliding-prism polarizing photometer, represent the best visual photometric work in existence, the probable error of a single set of measures remaining consistently but a little greater than ± 0.03 mag. Some points of general interest to variable star workers arise in the course of the revisions and are suitable for brief mention in these notes; the detailed revision will be published elsewhere.

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[1] *Contributions from the Princeton University Observatory*, No. 3.

The star UZ *Cygni* is out of the ordinary in the length of its period, its rather low density for an A-type star (0.01 in terms of the Sun), and in its probably very great distance from the solar system (hypothetical $\pi = 0''.0004$). Each eclipse lasts 2.5 days and the small bright star is totally obscured for 24 hours.

The new series of observations can not be satisfied by the light elements due to PICKERING, nor by the closely similar formula derived by HARTWIG. The following revised elements represent them satisfactorily, and also the earlier Harvard series (Vol. 69, part I):

$$\text{Min.} = \text{J. D. } 2415868.930 + 31^d.308 \cdot E.$$

HARTWIG announced in 1904 a secondary minimum of four-tenths of a magnitude[2] and gives annually an ephemeris for it in the *Katalog*. As the range of variation at primary is 1.86 mag. (revised value), such a secondary is impossible on the eclipse hypothesis, which permits one of at most but a few hundredths of a magnitude. WENDELL's observations, which are nearly contemporary with HARTWIG's announcement, confirm the absence of an appreciable secondary, which, for a circular orbit, should come at phase 15.7 days. The normal magnitudes at phases 13.2, 14.7, 15.4, and 16.7 days are 10.24, 10.33, 10.29, and 10.28, respectively, while 15 other observations give for the mean maximum magnitude 10.29 ± 0.02.

The revised photometric orbit differs very little from that originally computed, except that the inclination is 90° for both "uniform" and "darkened" solutions, and the "uniform" densities are slightly increased. The density of the fainter component is less than one-thousandth that of the Sun. Its spectrum is unknown, but an attempt will be made at Mount Wilson to determine its color index.

HARLOW SHAPLEY.

ABSOLUTE MAGNITUDE AND COLOR OF A VERY FAINT STAR.

In the preceding number of these *Publications* (December, 1915), Dr. VAN MAANEN announces the discovery of a faint, distant companion to the large proper motion star Pi. 2^h123. The coincidence of the direction and amount of the proper motions makes it practically certain that the two form a physical pair, and we may use the known parallax of the brighter star to determine the absolute magnitude of the fainter as soon as the apparent magnitude of the latter is measured. Because of the importance of knowing the intrinsic luminosity and spectral type of such stars, a series of observations has been made with the 60-inch reflector for the purpose of determining the magnitude and color of the faint companion.

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[2] *Astronomische Nachrichten*, **165**, 121, 1904.

The plates, each involving a polar comparison, are as follows:—

			No. Exposures		
No	Kind	Aperture	Pole	Star	Magnitude
2830	Seed "27"	60 in.	2	2	13.13
2831	"Iso"	60	3	2	11.59
2832	"Iso"	60	1	2	11.36
2833	Seed "27"	60, 32	2	2	13.19
2848	Seed "27"	32	2	2	13.38
2849	"Iso"	32	1	2	11.56

The magnitudes have been corrected for atmospheric extinction.

The adopted photographic magnitude is 13.24, the photovisual 11.50, and the resulting color index, + 1.74, corresponds to color class *m*4. The relation between color and spectrum for stars as red as this is not definitely determined for the Mount Wilson photometric system. Provisionally, at least, we are justified in assuming that the spectrum of the star is not bluer than type M.

Assuming as the parallax of this star the weighted mean of the values derived by FLINT, and SMITH and ELKIN for Pi. 2^h123, the absolute photovisual magnitude is 12.3 ± 0.7, the probable error including the large uncertanties in the parallax and the errors in the magnitudes. The luminosity of the star is only one-thousandth that of the Sun. It is, therefore, one of the faintest stellar objects on record.

HARLOW SHAPLEY.

THE SPIRAL NEBULA MESSIER 33.

A 34½-hour spectrum of the bright knot 10 minutes of arc *nf* the nucleus of *Messier* 33 was obtained with the 60-inch Cassegrain spectrograph,[1] using a short focus camera of which the scale is Hγ — K = 7^{mm}. Three bright lines only appeared, 5007, *Hβ*, *Hγ*, from which Mr. ADAMS obtained a radial velocity of — 278^{km}. An exposure of 29 hours on the nucleus with the same instrument gave an extremely weak plate, from which it was deduced that the spectrum was continuous.

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[1] "Radial Velocities of 6 Nebulæ." *Publications of the Astronomical Society of the Pacific*, December 1915.

A small spectrograph was next constructed to work at the Cassegrain focus, using an 18-inch collimator, a 39° O 102 prism and a Dallmeyer cinematograph lens ($F/A = 1.9$) of 3 inches focus. The scale is Hγ — K = 0.9^{mm}.

An exposure of 32 hours early in December gave a very strong spectrum of the nucleus together with a fair spectrum of the nebula itself for a distance of a minute of arc on either side. The spectrum of the nucleus is about F_0, and that of the nebula appears to be of the same type. Measures of this plate by both Mr. ADAMS and Miss BURWELL gave a radial velocity of the order of — 70^{km}.

Unfavorable weather has prevented the obtaining of spectra of other knots to determine whether there is a progressive change in type from the nucleus to the edge and also whether or not the difference in velocity means a rotation.

FRANCIS G. PEASE.

THE PARALLAX OF 61 CYGNI.

Eighteen exposures made at the 80-foot focus of the 60-inch reflector give as the relative parallaxes and proper motions of the components of the well-known double star 61 *Cygni*:—

$$61_1 \begin{cases} \pi = +0''.325 \pm 0''.011 \\ \mu_a = +4''.107 \pm 0''.028 \end{cases}$$

$$61_2 \begin{cases} \pi = +0''.320 \pm 0''.008 \\ \mu_a = +4''.107 \pm 0''.023 \end{cases}$$

To convert the relative values into absolute parallaxes we should add about 0''.002. The absolute parallax determined by KAPTEYN from the results of several observers (*Gron. Pub.*, No. 24) is + 0''.311. BOSS gives as the proper motions in α + 4.''164 and + 4''.132, respectively.

A. VAN MAANEN.

NOTE ON COMET *c* 1915 (TAYLOR.)

Comet *c* 1915 was first observed by Mr. TAYLOR at the Cape of Good Hope on December 2nd. The news of the discovery was cabled to England and reached Harvard Observatory somewhat delayed by the activities of the censors.

The first observation in this country was made by BURTON, at the U. S. Naval Observatory, on December 6th. On the next night AITKEN at Lick, VAN BIESBROECK at Yerkes, and WILSON at Northfield, obtained measures of its position. Thus far twenty observations have been received at the Students' Observatory, seventeen of which were made by the observers named above, the other three by Messrs. GREEN and SANFORD at the Lick Observatory.

A preliminary parabolic orbit was computed at Berkeley, by Miss SOPHIA H. LEVY and Mr. C. D. SHANE, and was telegraphed to Harvard College Observatory. It is published in H. C. O. Bulletin No. 595. This orbit was based on one-day intervals. The geocentric motion was unusually slow and the orbit was correspondingly uncertain.

A second orbit was attempted by the undersigned, based on an eight-day arc, also on the parabolic hypothesis. It was found impossible after repeated trials to secure a satisfactory representation of the observations. The run of the residuals showed quite definitely that a parabola would not yield satisfactory representation.

The next orbit, tho based on the previously computed parabola, was without assumption as to eccentricity. It was based on an arc of eleven days. This orbit furnished a satisfactory representation of the observations. The resulting elliptic elements, together with an ephemeris to February 1st, are given in L. O. Bulletin No. 276.

The nearest approach to the Earth occurred on the 3d of January, when the comet was 56,000,000 miles distant. The nearest approach to the Sun, or the perihelion passage, will take place on January 28th, when the comet will be at a distance of 135,000,000 miles from the Sun. Its brightness is slowly decreasing and is such that on the 1st of February it will be about nine-tenths as bright as it was on December 13th, when it was of about the eleventh magnitude. It will be favorably situated for some time, however. It is moving north, and is near opposition to the Sun. AITKEN states that the comet has a well-defined, tho faint, nucleus and that it is brighter photographically than visually.

The major axis of the orbit of about 280,000,000 miles, would indicate that the comet is a member of the *Jupiter* group. The eccentricity is approximately 0.5, the inclination to the ecliptic 14°, the longitude of the ascending node 114°, the longitude of the perihelion 107°, and the revolution period 5.3 years.

It is hoped that the comet will be observed as long as possible, as its elliptical character gives it unusual interest. Thus far, no identification with a previously known comet has been made, but it is not impossible that this may be done with a more definite orbit.

H. M. JEFFERS,
FERD. J. NEUBAUER.

STUDENTS' OBSERVATORY,
BERKELEY, CALIFORNIA.

PERSONAL NOTES.

Dr. CHARLES E. ADAMS, Government Astronomer of New Zealand, who has been in residence at the Lick Observatory as Martin Kellogg Fellow for the past year, sailed for New Zealand on the Maitai, on January 7, 1916.

Dr. W. W. CAMPBELL was one of the twenty-one official delegates of the United States to the Second Pan-American Scientific Congress, which held its sessions at Washington from December 27, 1915, to January 8, 1916. He also served as the delegate from the American Association for the Advancement of Science, and, with Professor SOLON I. BAILEY, represented the American Astronomical Society. At the joint session of the Congress and the American Association held on Monday evening, January 3rd, Dr. R. S. WOODWARD presided, and Dr. CAMPBELL gave an illustrated lecture on "The Evolution of the Stars."

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

MEASUREMENT OF THE CHANGE IN GRAVITY CAUSED BY THE MOON.

The diminution in the gravitation constant due to the position of the Moon had never been directly measured until the investigations of SCHWEYDAR, described in the present abstract (W. SCHWEYDAR: Änderung der Intensität der Schwerkraft durch den Mond, Sitz. kön. pr. Akad. d. Wiss., April, 1914), tho indirect evidence of the extremely minute change involved had been secured thru pendulum experiments. The paper is of great interest to the astronomer or geodesist, not only because it affords a direct confirmation of a point in gravitational theory and additional evidence bearing upon the question of the Earth's effective rigidity, but also because it is an excellent example of an experiment carried out with exceedingly simple instrumental means. For the instrument used, SCHMIDT'S gravimeter, is so simple in its essentials that it could doubtless be rigged up in a few hours in any small laboratory. It consists of a disk about two and a half inches in diameter, provided with two small hooks at points 180° apart; fastened to the middle of the disk on the under side is a small weight of about twelve ounces. The disk and attached weight are suspended in a long glass jar by means of a spiral spring of steel wire somewhat over thirty inches long. To the two small hooks are attached two very fine wires, the other ends of which are fastened to the walls of the glass vessel at opposite points, somewhat above the plane of the disk. These wires support a very small fraction of the weight of the disk. If now the long spiral spring is twisted slightly at its upper end the disk will be slightly rotated, so that the two fine wires no longer lie in the same plane, and in this position the apparatus is extraordinarily sensitive to a small change in the weight of the disk; any such small change in weight will operate to rotate the suspended system slightly, a rotation which can be read off from a beam of light reflected from a small mirror attached to the suspended system.

So sensitive is the gravimeter that it was necessary to place it in an underground chamber eighty feet below the surface.

where it has been found that the temperature varies but 0°.2 per year, and the records were made by photographic means, inasmuch as the heat radiated from the body of an observer entering the subterranean chamber would affect the records for several hours. The apparatus, furthermore, acted as a pretty fair barometer; tho the suspended parts displaced less than two cubic inches of air, the difference in the buoyancy of even this small amount of air at different barometric pressures showed very clearly and had to be allowed for; even very minute, short-period oscillations in pressure as shown by a very sensitive barometer were recorded!

The observations extended over a period of 295 days and agree well with other investigations in placing the effective rigidity of the Earth as two or three times that of hardened steel.

The results, in combination with pendulum data, afford a method for determining the actual heights of the lunar tides caused in the elastic Earth; the maximum amplitude of this half daily tide in the solid Earth is about four and a half inches at Potsdam. H. D. Curtis.

A "Perturbation Machine."

The tidal theory is one of exceeding complexity, and into it enter a multitude of interacting components of widely different magnitudes and periods, yet we know that all the varying effects of appreciable influence can be taken account of and combined into a single tidal curve by that ingenious mechanism known as the tide-predicting machine. We have the tidal machine and the harmonic analyzer as examples of what can be done by mechanical means in the solution of problems of great complexity, but, even with such examples before us, the mere idea that a machine is possible which should solve mechanically the question of the perturbations of a planet over long periods of time is something of a strain on the credulity of any who realize how complicated are the mathematical processes and how extended are the computations involved in this department of celestial mechanics. At the present rate of discovery it will be only a few years before the number of minor planets known will pass the thousand mark, and the labor of "keeping track" of the orbits of all these objects has already become so great that it has been more than once suggested that the only possible course for the astronomical world is to admit itself beaten, let the less interesting members of the asteroid family drift into oblivion, and keep track of the perturbations and orbits of only a few of the more interesting planetoids. If, on the other hand, we are not to neglect any of these bodies, something in the nature of a "perturbation machine" would seem to be an absolute necessity.

The plan and preliminary specifications of such a "perturbograph" have been drawn up by SUNDMANN, the clever Finn whose brilliant work on the "Problem of Three Bodies" seems to have opened a new chapter in celestial mechanics; his name is sufficient guarantee that all the essential factors in this complex problem have been taken into account ("Plan d'une Machine destinée à donner les Perturbations des Planètes," par KARL F. SUNDMANN, Särtryck ur Festskrift Tillegnad ANDERS DONNER, Helsingfors, 1915). It was SUNDMANN of whom Sir GEORGE GREENHILL said in a Presidential Address to the Mathematical Association (quoted from *The Observatory*, Aug. 1915):—

> "No sooner had POINCARÉ declared the Problem of the Three Bodies insoluble than SUNDMANN showed how the divergency of the series required to hold for infinite eternity of Time, past and future, could be cured by a simple change of the variable."

The machine has not yet been constructed. This brochure is devoted solely to a general description of the plans for such a machine, with schematic drawings of the various portions; from these it is very difficult to get an idea of the machine in its entirety or to see in just what way the various portions are combined. Suffice it to say that the machine will be very complicated, apparently so much so that a tide-predicting machine appears by contrast to be a relatively simple mechanism. To quote SUNDMANN's general description of the machine and its functions:—

(1) A mechanism imitates the movements of the perturbing and perturbed planets in such a manner that their relative positions in space are indicated upon the scale given by the relative positions of certain elements of the machine.

(2) According to the relative positions of these elements, other elements are constrained mechanically to indicate by their relative positions the magnitudes of the perturbing forces, and according to the position of this second set of elements, a third set indicates the derivatives of the perturbations.

(3) By combining these final elements with integrators, the perturbations are obtained, which are recorded at the desired epochs.

(4) As the registered perturbations increase in the machine, the position of the perturbed planet is to be automatically corrected for the values of the perturbations.

The author states it as his belief that the perturbations can be secured by such a machine, accurately constructed, to within less than one per cent of their magnitude.

His plan is to give a speed of movement to the perturbograph such that one revolution of *Jupiter* would take about seven minutes, so that an interval of ten days would correspond to one second. The setting up of the instrument would take about twenty-five minutes, if made by two persons. With the aid of proper auxiliary tables it should be possible to determine the perturbations for all the oppositions during a revolution of *Jupiter*, i. e., for about twelve years, in one hour.

It is to be hoped that the author may find it possible to proceed to the construction of the ingenious machine which he has devised. Tho its first cost might be considerable, it would perform in a short time the work now laboriously executed by large staffs of computers in connection with the ephemerides of the asteroids. H. D. Curtis.

Temperature and the Force of Gravity.

In a letter to *Nature*, 96, 143, entitled "*The Masses of Heavenly Bodies and the Newtonian Constant*," Dr. P. E. Shaw of the University College, Nottingham, questions the constancy of the Newtonian gravitational factor G. He believes, as the result of certain experiments by himself, that the gravitational force exerted by a mass at a constant distance varies with its temperature. Quoting a passage from Dr. Shaw's letter:—

"I have recently concluded a long research on the value of G up to 250° C., and I have found an increase in that 'constant' of about 1 in 10^5 per 1° C. The full results I hope to publish shortly."

The letter devotes itself chiefly to a consideration of the influence of the proposed generalization of the law on the computed values of the masses of the Sun and planets.

Effects such as the one Dr. SHAW believes he has found have been sought by earlier investigators with negative results. His extension of the law of gravitation, if established, would be so far-reaching in its influence that its importance could hardly be over-estimated. It is to be hoped that the complete account of his experiments may soon be forthcoming.

W. H. W.

A FAINT STAR OF LARGE PROPER MOTION.

Mr. R. T. A. INNES has been one of the most energetic advocates of the merits of the blink-microscope "in picking out unusual motions or objects upon a pair of plates. In Circular No. 30 of the *Union Observatory* he gives a new example of the value of this instrument which has resulted from the comparison of two photographs of the region around *α Centauri*, taken at dates separated by 5.3 years. A small star was found, 2° 13′ from *α Centauri*, which has a proper motion of about 5″ annually. The precise value is slightly in doubt because the images on one of the plates are not very satisfactory. Only five stars are known whose proper motions exceed this value, and all of them are much brighter than this star, which has a photographic magnitude of 12.0 on the Harvard scale. Visually the star appears to be about tenth magnitude. Its position for $1900 + t$ is given as R. A. $14^h\,22^m\,55^s - 0^s.65\,t$, Decl. $-62°\,1'.6 + 1''.6\,t$.

R. G. AITKEN.

GENERAL NOTES.

The Orbit of Σ 2026 = β's G. C. No. 7561.—In the *Astronomische Nachrichten,* No. 4823, Professor WIRTZ publishes an orbit of this binary star which was found among the papers left by Dr. MARTIN MATZDORFF, who was killed at Ypres on November 2, 1914. The elements are:—

MATZDORFF	AITKEN
T = 1907.64	1909.25
ω = 162°.23	203°.0
Ω = 10.18	2.4
i = 45.73	50.45
a = 1″.779	1″.56
e = 0.7222	0.66
P = 242°.10	163.3

My own elements, given in Volume XII of the *Lick Observatory Publications,* are printed for comparison with MATZDORFF'S. Tho there is a marked difference, especially between the two periods, the two orbits represent the observations to 1912, inclusive, equally well. MATZDORFF'S elements, however, gave the smaller residuals for my measures in 1914 and for WIRTZ'S in 1915, as the following figures show:—

				O—C.			
	θ_0	ρ_0	Obs.	MATZDORFF.		AITKEN.	
1914.44	105.6	0″.51	A	+ 4°.0	+ 0″.03	+ 6°.6	+ 0″.08
1915.53	91.3	0 .54	W	— 0 .4	+ 0 .02	+ 6 .6	+ 0 .07

Both orbits are necessarily uncertain because the observations do not clearly define the apastron end of the apparent ellipse.

R. G. A.

Variable Nebula N. G. C. 6729.—H. KNOX SHAW publishes an interesting note in Bulletin No. 16 of the Helwan Observatory in which he states that photographs taken in the years 1911-1915 have definitely confirmed the belief of earlier observers that this nebula is variable. It is attached to the irregularly variable star R *Coronæ Australis,* and the new photographs establish "that the variation of the nebula is intimately connected with that of the star." Further study is in progress.

The Monthly Evening Sky Map.—With the December, 1915, number, the *Monthly Evening Sky Map*, completed the tenth year of its publication, and in the January, 1916, number, its founder and publisher, Mr. Leon Barritt, gives an interesting account of its establishment and growth. In the course of his article he remarks upon the general lack of knowledge of even the simplest astronomical facts, and attributes this to the neglect of astronomy in our schools. "I have found," he says, "that astronomy is not taught in a single grammar school in the United States. A few high schools give it consideration in connection with physical geography, and in the colleges and universities it is elective, and very few take it up." As 75 per cent of the children in this country leave school when they graduate from the grammar school, the prevailing ignorance of astronomy is readily intelligible.

Mr. Barritt is doing useful work in publishing the *Monthly Evening Sky Map*, which gives the data, with maps, to enable anyone to trace the constellations visible in the evening sky and to identify and follow the motions of the planets, and it is a pleasure to recommend the little journal to every one who is interested in astronomy.[1]

In this connection attention is called to the fact that Miss Mary E. Byrd is organizing a section of the Society for Practical Astronomy, to be devoted to the practical teaching of astronomy. This and every other effort made to awaken and develop an interest in our science should receive our heartiest support.

Two New Observatories.—*Popular Astronomy* reports that Mr. John H. Darling, of Duluth, Minnesota, has promised to build an observatory on one of the public play-grounds of that city. The building is to be of brick, with a 20-foot dome and an adjoining library and the telescope, a 9-inch refractor.

Sirius, for November, 1915, has a note on the establishment of a private observatory in Córdoba, Argentina, by Senor Federico Schneider. The principal instrument is a refractor of 15^{cm} (6 inches) aperture, which is to be used chiefly in the observation of variable stars.

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[1] The annual subscription price is $1.00. Address, Leon Barritt, 150 Nassau St., New York, N. Y.

New Zealand Ensign.—The New Zealand *Nautical Almanac and Tide Tables* contains the following item, which may be of general interest:—

"The New Zealand ensign shall be the blue ensign of the Royal Naval Reserve, having on the fly thereof the Southern Cross as represented by four five-pointed red stars with white borders. . . . .

"The following is a description of the stars referred to, and their positions on the flag:—

"The centres of the stars forming the long limb of the cross shall be on a vertical line on the fly, midway between the Union Jack and the outer edge of the fly, and equidistant from its upper and lower edges; and the distance apart of the centres of the stars shall be equal to thirty-six sixtieths of the hoist of the ensign.

"The centres of the stars forming the short limb of the cross shall be on a line intersecting the vertical limb at an angle of 82° therewith, and rising from near the lower fly corner of the Union Jack towards the upper fly corner of the ensign, its point of intersection with the vertical line being distant from the centre of the uppermost star of the cross twelve-sixtieths of the hoist of the ensign. The distance of the centre of the star nearest the outer edge of the fly from the point of intersection shall be equal to twelve-sixtieths of the hoist of the ensign, and the distance of the centre of the star nearest the Union Jack from the point of intersection shall be equal to fourteen-sixtieths of the hoist of the ensign.

"The star nearest the fly edge of the ensign (δ, 3.1 mag.)[1] shall measure five-sixtieths, the star at the top of the cross (γ, 1.6 mag.) and that nearest to the Union Jack (β, 1.5 mag.) shall each measure six-sixtieths, and the star at the bottom of the cross (α = 1.1 mag.) shall measure seven-sixtieths of the hoist of the ensign across their respective red points, and the width of the white borders to the several stars shall in all cases be equal to one one-hundred-and-twentieth of the hoist of the ensign."

* * *

CARL AXEL ROBERT LUNDIN died at his home in Cambridge, Mass., on November 28, 1915. Mr. LUNDIN was connected with the ALVAN CLARK & SONS for many years, and had a share in the construction of the lenses for the 36-inch Lick refractor and the 40-inch Yerkes refractor. Later he became the head of the firm, which has continued the work of figuring both lenses and mirrors for use in large and small telescopes.

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[1] The Greek letters and magnitudes are not given in the official description of the ensign.

Branch Hydrographic Office, San Francisco, January 4th.—Captain J. H. **Trask** of the steamer Sonoma reports to this office that on December 2, 1915, in latitude south 22° 08′, longitude east 177° 47′, passed thru large quantities of pumice dust and stones. The whole mass had a dirty green color and extended for several miles around the ship.

Charles P. Huff,
Lieut.-Com. U. S. N., in charge.

(*S. F. Chronicle*, Jan. 5, 1916.)

Minutes of the Meeting of the Board of Directors of the Astronomical Society of the Pacific, Held in the Rooms of the Society on January 20, 1916, at 7:30 p. m.

There were present: President R. G. **Aitken** and Directors **Townley**, **Cushing**, **Costa**, **Markwart**, **Cornish**, **Leuschner** and **Richardson**.

Communication was read from Prof. W. J. **Hussey**, Director of the Detroit Observatory, asking that he be made a Life Member. He was elected by unanimous vote.

Mr **Harlow Shapley** was elected as an Active Member of the Society.

The matter of increasing the membership of the Society and reducing the dues was introduced by President **Aitken** and discussed by the Board

On motion of **Townley**, seconded by **Cushing**, President **Aitken** was appointed a committee of one, with authority to add such other members as he may think fit, and instructed to submit recommendations at the next meeting of the Board.

Attention of the Board was called to the fact that little use is made of the library of the Society—and opinions invited as to the policy of turning the books on hand over to one of the large popular libraries of the city of San Francisco.

The Library Committee was instructed to investigate the matter and report at next meeting.

Adjourned

D. S. Richardson, *Secretary*

Minutes of the Annual Meeting of the Astronomical Society of the Pacific, Held in the Assembly Hall of the Phelan Building, San Francisco, on January 29, 1916, at 8:00 o'clock p. m.

President R. G. **Aitken** in the chair.

On motion of Director **Leuschner** the minutes of the last annual meeting were approved as printed.

Mr. Cushing, Chairman of the Finance Committee, reported that the books and accounts of the Society had been audited and that all property of the Society had been properly accounted for by the Treasurer.

The following report of the Comet-Medal Committee was read by the Secretary and accepted:—

REPORT OF THE COMET-MEDAL COMMITTEE.

Mount Hamilton, January 20, 1916.

The comets for the year 1915 have been the following:—

1915a—Unexpected comet discovered by John E. Mellish at Cottage Grove, Wisconsin, on February 10th.

1915b—Winnecke's periodic comet photographed by M. H. Thiele, Hamburg, Germany, on April 4th.

1915c—Periodic comet, *Tempel*$_2$, observed on its return by P. T. Delavan, La Plata, Argentina, on May 16th.

1915d—Unexpected comet discovered by John E. Mellish, Cottage Grove, Wisconsin, on September 13th.

1915e—Unexpected comet discovered by C. J. (?) Taylor, Cape of Good Hope, South Africa, December 2nd.

In accordance with the statutes the Donohoe Comet-Medal has been awarded for the discoveries of comets a, d, and e.

Respectfully submitted,
Committee on the Comet-Medal:
W. W. Campbell,
R. H. Tucker,
Heber D. Curtis.

The Chairman of the Library Committee reported that there had been no additions to the books of the library during past year.

The Society then proceeded to the election of a Board of Directors and a Publication Committee for the ensuing year.

The following nominations were made by R. T. Crawford, Chairman of the Nominating Committee:—

For Board of Directors—W. W. Campbell, H. D. Curtis, Chas. Burckhalter, Wm. H. Crocker, C. S. Cushing, F. V. Cornish, B. L. Hodghead, A. O. Leuschner, A. H. Markwart, D. S. Richardson, S. D. Townley.

For Publication Committee—R. G. Aitken, H. D. Curtis, H. Shapley,

The President appointed Messrs. Costa and Brasch as tellers and announced that the ballots would be collected and counted later in the evening.

President Aitken then proceeded to deliver his address incidental to the award of the Bruce Gold Medal for the year 1916, which goes to Prof. Geo. E. Hale, Director of the Solar Observatory at Pasadena.

The address, which is printed elsewhere, was a generous appreciation of the merits, and distinguished services to astronomy, of Prof. Hale. At its close, Prof. Hale, who was present, acknowledged the honor conferred upon him in a very gracious speech, claiming that any honors coming to him should be shared equally with those who have labored with him.

Following the presentation of the medal, Dr. H. D. CURTIS, of Lick Observatory, addressed the Society upon the subject of "Recent Theories in Stellar Evolution." The fascinating subject was illustrated by many lantern slides and closely followed by an appreciative audience of about two hundred people.

At the close of the speaking, the tellers collected and counted the ballots, which showed that the officers as above nominated had been duly elected to serve for the ensuing year.

Adjourned.

D. S. RICHARDSON, *Secretary.*

REPORT OF THE TREASURER OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE FISCAL YEAR ENDING JANUARY 29, 1910.

GENERAL STATEMENT.

Assets of the Society	
In Bonds, estimated value	$17,154 69
Cash in Bank to credit of Funds	2,732 03
Total	$19,886 72
Liabilities of the Society, none.	

CASH STATEMENTS BY FUND.

WILLIAM ALVORD FUND.

Dr.		
To	Balance January 30, 1915	$ 384 87
	Interests and Dividends in 1915	210 52
	Total	$ 595 39
Cr.		
By	Transfers to General Fund	210 52
	Balance January 29, 1916	$ 384 87

LIBRARY FUND.

Dr.		
To	Balance January 30, 1915	$ 99 78
	Interests and Dividends in 1915	163 84
	Total	$ 263 62
Cr.		
By	Transfers to General Fund	183 84
	Balance January 29, 1916	$ 79 78

JOHN DOLBEER FUND.

Dr.		
To	Balance January 30, 1915	$ 467 98
	Interests and Dividends in 1915	233 88
	Total	$ 701 86
Cr.		
By	Transfers to General Fund	233 88
	Balance January 29, 1916	$ 467 98

LIFE MEMBERSHIP FUND.

Dr.		
To Balance January 30, 1915	$	71 07
One Life Member		50 00
Interests and Dividends in 1915		92 86
Total	$	213 93
Cr.		
By Transfers to General Fund		92 86
Balance January 29, 1916	$	121 07

BRUCE MEDAL FUND.

Dr.		
To Balance January 30, 1915	$	635 67
Interests and Dividends in 1915		148 99
Total	$	784 66
Cr.		
By Expenditures, 2 Medals		220 00
Balance January 29, 1916	$	564 66

DONOHOE COMET MEDAL FUND.

Dr.		
To Balance January 30, 1915	$	923 83
Dividends in 1915		37 30
Total	$	961 13
Cr.		
By Balance January 29, 1916	$	961 13

GENERAL FUND.

Dr.		
To Balance January 30, 1915	$	324 74
Receipts from Dues		406 25
Sales of *Publications*		72 50
Dolbeer Fund		233 88
Alvord Fund		210 52
Library Fund		183 84
Life Membership Fund		142 86
Bruce Medal Fund		14 44
From a Friend		2 50
Total	$	1,591 53
Cr.		
By Blair-Murdock Co., printing	$	783 50
Rents		212 50
Salaries		240 00
Mercantile Trust Co., care of bonds		36 34
Sunset Publishing Co., cuts		27 30
Lantern service		10 00
Taxes		7 65
Insurance		8 40
Crocker safe deposit box		4 00
Engraving		3 60
Shelving		2 50
Postages		23 20
Transfer to Life Membership Fund		50 00
Total	$	1,438 99
Balance January 29, 1916	$	152 54

SECURITIES HELD BY THE SOCIETY.

These securities are all of the face denominations of $1,000, and the values given represent their original cost to the Society.

Life Membership Fund.	
One South Pacific Coast Railroad Company's 1st mortgage, guaranteed 4 per cent Gold Bond, No. 3406. Principal due July, 1937; interest payable in January and July.	$1,000 00
One Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No 712. Principal due July 1, 1934; interest payable January 1st and July 1st.	990 25
Alexander Montgomery Library Fund.	
One Oakland Transit consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4328. Principal due July, 1932; interest payable January and July	1,041 00
One Contra Costa Water Company's 5 per cent Gold Bond, No. 1665. Principal due January, 1915; interest payable January and July.	1,035 00
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 714 Principal due January 1, 1934; interest payable January 1st and July 1st.	497 50
One Blue Lakes Water Company 6 per cent 1st mortgage Gold Bond, No. 380. Principal due 1938; interest payable March 15th and September 15th	1,001 25
Bruce Medal Fund.	
One Bay Counties Power Company 1st consolidated mortgage 5 per cent sinking fund Gold Bond, No 1636. Principal due September, 1930, interest payable March and September.	1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6836. Principal due September, 1922; interest payable in March and September.	977 22
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No 714. Principal due January 1, 1934; interest payable January 1st and July 1st.	497 50
[illegible] Fund.	
One South Pacific Coast Railway Company's 1st mortgage 4 per cent guaranteed Gold Bond, No. 3407. Principal due July, 1937; interest payable in January and July.	1,000 00
One Oakland Transit consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4329. Principal due July, 1932; interest payable January and July	1,040 00
One Bay Counties Power Company 1st consolidated mortgage 5 per cent sinking fund Gold Bond, No. 1637. Principal due September, 1930, interest payable March and September.	1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6837 Principal due September, 1922; interest payable in March and September.	977 22
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 713 Principal due January 1, 1934; interest payable January 1st and July 1st.	497 50
[illegible] Fund.	
Two Contra Costa Water Company's 5 per cent Gold Bonds, Nos. 87 and 1666. Principal due January, 1915; interest payable in January and July.	2,071 50
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond No. 713. Principal due January 1, 1934; interest payable January 1st and July 1st.	497 50
One Blue Lakes Water Company 6 per cent 1st mortgage Gold Bond, No. 381 Principal due 1938; interest payable March 15th and September 15th	1,001 25

One Moulton Irrigated Lands Company 6 per cent 1st mortgage Gold Bond, No. 144. Principal due December 15, 1918; interest payable June 15th and December 15th	1,000 00
Seventeen bonds, original cost	17,154 69

NOTE.

This Society is the owner of three of the underlying 5% Gold Bonds of the Contra Costa Water Company which came to maturity in January, 1915. The said corporation defaulted in the payment of interests due on July 1, 1914, and its affairs are now in process of reorganization.

By authority of the Finance Committee, these bonds were deposited by the Treasurer, under date of August 23, 1915, with the Reorganization Committee of The People's Water Company, known as the Bowles-Drum Committee and represented by the Savings Union Bank and Trust Company of San Francisco.

The July, 1914, coupons on these bonds were paid in September, 1915, and there is at present due from this source, aside from the face value of the bonds, the sum of $225.00.

A report of the Reorganization Committee of the People's Water Company, bearing date of January 8, 1916, announces that gratifying progress is being made in the incorporation of a new company and the preparation of new securities to take the place of the present outstanding bonds.

The Society is also the owner of one 6% First Mortgage Gold Bond of the Moulton Irrigated Lands Company, No. 144.

By authority of the Board of Directors, this bond was withdrawn from the custody of the Mercantile Trust Company in December, 1915, and deposited with the First Federal Trust Company, where it is now held under an option given to this Society to take its face value in cash, plus a bonus of $10.00, or to accept the bond of a new issue, in equal amount and interest, plus a bonus of $10.00.

During the year 1915 one Life Member was added to the Society and eleven Active Members. There were seven resignations.

D. S. RICHARDSON, *Secretary-Treasurer.*

Accounts examined and found correct.

CHARLES S. CUSHING,
FRANK V. CORNISH,
J. COSTA,
Auditing Committee.

MINUTES OF THE MEETING OF THE NEWLY ELECTED BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, 725 PHELAN BUILDING, SAN FRANCISCO, ON JANUARY 29, 1916, AT 10:00 P. M.

There were present Directors H. D. CURTIS, C. S. CUSHING, F. V.

CORNISH, A. O. LEUSCHNER, A. H. MARKWART, S. D. TOWNLEY and D. S. RICHARDSON.

The meeting was called to order by Director CUSHING and proceeded at once to organize by the election of the following officers for the ensuing year:—

For President—S. D. TOWNLEY.

First Vice-President—C. S. CUSHING.

Second Vice-President—H. D. CURTIS.

Third Vice-President—A. H. MARKWART.

Secretary and Treasurer—D. S. RICHARDSON.

President TOWNLEY appointed the following committees:—

Finance Committee—C. S. CUSHING, W. H. CROCKER and A. H. MARKWART.

Library Committee—D. S. RICHARDSON, F. V. CORNISH and F. E. BRASCH.

Action upon the Comet-Medal Committee was deferred by the President for further consideration.

Adjourned.

D. S. RICHARDSON, *Secretary*.

blications of the Astronomical Society, &c.

OFFICERS OF THE SOCIETY

S. D. Townley	*President*
C. S. Cushing	*First Vice-President*
H. D. Curtis	*Second Vice-President*
A. H. Markwart	*Third Vice-President*
D. S. Richardson	*Secretary and Treasurer*

Board of Directors—W. W. Campbell, H. D. Curtis, Chas. Burckhalter, Wm. H. Crocker, C. S. Cushing, F. V. Cornish, B. L. Hodghead, A. O. Leuschner, A. H. Markwart, D. S. Richardson, S. D. Townley.

Publication Committee—R. G. Aitken, H. D. Curtis, H. Shapley.

Finance Committee—C. S. Cushing, W. H. Crocker, A. H. Markwart.

Library Committee—D. S. Richardson, F. V. Cornish, F. E. Brasch.

NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished free of cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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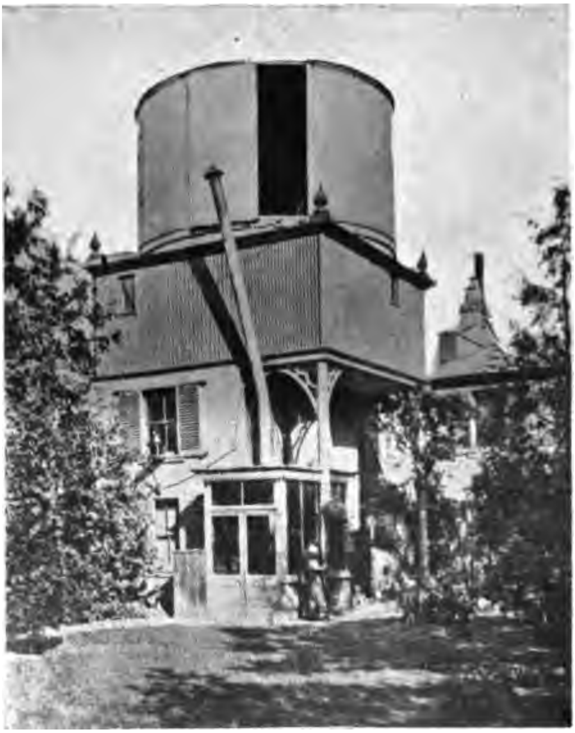

Sir William Huggins' Observatory, Upper Tulse Hill, London.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

Vol. XXVIII. San Francisco, California, April, 1916 No. 163

WORK FOR THE AMATEUR ASTRONOMER.

By George Ellery Hale.

I. *Introduction*[1]

No chapters in the history of science are more inspiring than those which recount the deeds of the amateur. Hampered, it may be, by lack of equipment, situated where the conditions for research are not of the best, and often compelled to devote his best hours to other pursuits, the amateur, rising above all discouragement, has continued to pour a flood of new ideas and significant observations into the ever-widening sea of scientific knowledge. Many a great name is associated with a modest beginning, and many a discovery has been made with inexpensive apparatus. Galileo and Newton, during their boyhood days, foreshadowed in their model windmills, water-clocks and other mechanical contrivances the latent ability which ultimately found full expression in the first refracting and reflecting telescopes and in other instruments and researches. Bessel, an apprenticed clerk in a German mercantile house, began his astronomical career by measuring the longitude of Bremen with the aid of an ordinary clock and an improvised sextant of his own design. Herschel, the organist of Bath, after constructing a 2-inch telescope, built for himself larger and larger instruments, and made contributions to every department of astronomy. Schwabe, the apothecary of Dessau, recording sun-spots from day to day for forty-three years with his small but "imperturbable telescope," discovered that their number waxes and wanes in the now well-known sun-spot period. Carrington, following Schwabe's example in his little observatory at Redhill, found that spots near the equator are carried westward more rapidly by the solar rotation than those in higher latitudes, and accumulated a great volume of valuable drawings and sun-spot statistics which are still in constant use by astronomers. Lassell, an English brewer, and Bond, who began his astronomical work while carrying on his trade in Maine as a watchmaker, discovered *Hyperion,* the seventh satellite of *Saturn,* on the same evening. Burnham, engaged throughout the day in the Chicago law-courts, spent his nights in observation with a 6-inch telescope, and discovered nearly five hundred new double stars. Huggins, undaunted by the smoke and fog of London, demonstrated at his Tulse Hill Observatory the gaseous nature of nebulæ and laid the foundations of the observational study of stellar evolution. Such illustrations might be given in large numbers from the records of astronomy, and multiplied many fold from the general history of science. They would include such notable cases as Darwin, whose work was done with the simplest of means, largely in the quiet of his home and undisturbed by the trend of contemporary thought; Faraday, the blacksmith's son and bookbinder's apprentice, essentially without education except the little derived from Davy's popular lectures on science at the Royal Institution; and Lord Rayleigh, who prefers his home workshop, with its simple facilities, to the extensive equipment of the Cavendish Laboratory.

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[1] This is the first of a series of articles by Messrs. Hale and Snow, which will explain how to build a small coelostat telescope with various accessories, and describe a series of observations and experiments in solar physics.

But neither in limited or unlimited resources nor in association with public or private laboratory do we find the criterion that marks the amateur. Nor is he to be mistaken for the dilettante of the popular imagination. The amateur is in fact a true lover of knowledge for its own sake, one who works because he cannot help it, swept on by a passion for research which he attempts neither to explain nor to curb, an enthusiasm which carries him over obstacles too high to be surmounted by the perfunctory student or the man without zeal. To the sane enthusiast, whether his talents be large or small, great advances are possible. An impelling interest, even if backed by only a very slender stock of knowledge, may accomplish more than all the learning of the schools.

While it is fortunately true that the amateur, in professional guise, is often found in the great university laboratory or the endowed observatory, he usually begins his work at home and without expensive appliances. The passion for research springs early, and the boy of twelve may already feel within him the desire to add to the world's knowledge. He consults his books, and is fascinated by the experiments they outline. Who can forget his thrill of excitement when the bubbles of oxygen, issuing from the heated retort, rose one by one thru the water-filled bottle, inverted over its tank! The delicious possibility of an explosion (realized all too often with prematurely ignited jets of hydrogen!) and the proud consciousness of actually venturing into the field of the original investigator, are experiences to be felt but not described. Then there was the winding of the first induction coil, the anxious test of the length of its spark, and the dim realization that here was an instrument of research applicable in many fields. In another province the return of spring and the breaking of the ice in the ditches meant exciting pursuits of the wily Cyclops and the agile Branchipus, or the lesser forms of life in the marvelous world of rotifers and vorticellæ. In recent years, as I have pushed with larger and larger telescopes into the depths of space, I have often been forced to confess that the astronomer never beholds sights more wonderful than those which a drop of ditch-water, on the stage of the cheapest microscope, will afford to any boy.

But while the observation of natural objects, the collection of specimens, or the performance of simple experiments may content many beginners, there are those who yearn to advance into the actual work of original research. To them, and perhaps to others, a series of connected experiments or observations, sufficiently varied to be attractive, but so contrived as to lead step by step into some profitable field of investigation, should be more interesting than the isolated phenomena more commonly described. If properly chosen, such experiments may serve as an introduction to the methods of the investigator and a stimulus to individual effort. By suggesting the unbounded opportunities for discovery which lie open in every department of science, they may also encourage the beginner to undertake a serious study of his subject and thus to prepare himself fully for the work of investigation.

What, then, does the beginner in science need? Judging from my own experience, I think he should first feel the stimulus which comes from reading of the great discoveries in any field of science, in the words of the discoverers themselves. These will inspire him to work, and convince him that knowledge is not a sealed book but an open manuscript, to which he may hope to contribute paragraphs or even chapters. He must learn of the many ways in which advances may come: by long-continued observations, carefully discussed; by the quick application of new ideas to the interpretation of old phenomena; by the invention and use of new instruments; by increased precision of measurement; by the recognition of relationships between seemingly unrelated things. He must be led to see that important discoveries do not necessarily demand expensive instruments, but result quite as often from the skillful use of the simplest means. He must realize that he, like others before him, can improvise these means, and apply them in real research. He must learn to cultivate an open mind, skilled in the art of devising explanations of his observations, but free from the prejudices which surround the man of one idea. He must know of the many laboratories and observatories where research is in progress, and become familiar with that great company of investigators who even in these days of war continue to widen knowledge. And in doing these things he must bear in mind that while he, too, may hope to join this company, he can do so only by showing good sense and good judgment, publishing no results until they have been amply verified, and adopting every possible means to extend his education and widen his experience.

To the would-be investigator, dimly perceiving for the first time the boundless possibilities of original research, there is no such stimulus as that to be derived from direct contact with the masters of his subject. He should not be content with some second-hand description of their work, but go straight to the original sources, and read what was written in the very heat of progress. Thus he may feel with them the dawning consciousness of new lands to be explored and experience some of the delight which they felt when they first passed from the known into the unknown. Moreover, he may best realize in this way how simple are the tools so often employed to attain the most important ends, and recognize the advantage of cultivating an alert and optimistic mind, sensitive to new impressions and aware of the opportunities which are ever open to the ready inquirer.

Having made a brief survey of his subject, which should be followed by wide reading in the classics of science and in its extensive periodical literature, the beginner will wish to try his own hand. Let us suppose him to have chosen the field of astronomy. First of all he will be fascinated by the stars and by the many problems they offer for solution. The vast extent of the universe, the beautiful phenomena of star-clusters, nebulæ and comets, the changing light of the variable stars, the surface markings of the Moon and the planets—these and many other phenomena will appeal to his imagination and to his instinct for investigation. Last of all, perhaps, he may realize the unique opportunity for widely varied study which the Sun affords, and understand why this is so. For all the other stars are very far away—so far that they appear merely as needle points of light in the most powerful of telescopes. To see them as we see the Sun, to discern their huge disks, the spots on their surfaces, the flames in their atmospheres, we must approach them closely, and there is no prospect that any telescope, however powerful, will ever make this possible. They remain, under the highest magnification, as extremely minute points of light.

How fortunate, then, that one star is so near at hand! This one exception, our own Sun, is proved in a score of ways to be a perfectly typical star, similar in chemical composition, in size and in structure to millions of other stars in the remote distances of space. It is so near us that any telescope will show its disk and the spots that come and go on its surface. These and its other phenomena are most varied in character, constantly changing in number and in form and suggesting problems of every kind for solution. With simple instruments, easily constructed, they can be brought within the amateur's range. If fortunate enough to have access to a small shop, he can build his own telescope, procuring the optical parts at very slight expense from the nearest spectacle maker. If not, he may employ a local machinist to do the work which is beyond his capacity.

Once constructed and installed, the telescope will be ready for work of real value, as it will yield photographs of the Sun suitable for such studies as those of Schwabe and Carrington. But the young solar physicist, who has read of the marvelous discoveries of the spectroscope and its almost unlimited possibilities when applied to the study of the Sun, will not rest content without the support of this powerful ally. Indeed, he will have realized that the spectroscope is even more important in solar research than the telescope itself, tho the combination of the two is usually essential. Thus he should proceed to complete his outfit by constructing a spectroscope, which may advantageously take the form of a spectroheliograph, since this instrument can be used both as a spectroscope and as a means of photographing the invisible phenomena of the solar atmosphere. Fortunately this apparatus is extremely simple and inexpensive, and can easily be built by the amateur himself.

Thus equipped, the amateur astronomer is prepared for a long series of fascinating observations. He will first wish to repeat Kirchhoff's epoch-making discovery, and prove the existence of sodium and iron and other elements in the Sun. This experiment can be made visually, but the photographic method is far more satisfactory, and should be applied without delay. Nothing is more striking than to see a long strip of the solar spectrum recorded on the photographic plate, side by side with the hundreds of bright lines of the iron spectrum, each of which has a solar counterpart. The amateur will at once realize the certainty of spectrum analysis, and understand how Rowland, testing substance after substance against the Sun, finally identified a large majority of the terrestrial elements as glowing gases in the solar atmosphere.

Thus made acquainted with the gaseous surroundings of the Sun, he will wish to observe their remarkable forms. Ordinarily concealed by the brilliant light of the sky, the red solar prominences rise high above the disk of the Sun when it is obscured by the Moon in a total eclipse. But we need not wait for one of these rare events, as Janssen and Lockyer showed in 1868 how a spectroscope can be used on any clear day to render these flames visible. Having watched their changing forms and studied their spectra, the amateur will wish to photograph them, which he can easily do with his spectroheliograph. And this will lead him to take another step.

It is evident enough that the chromosphere and prominences which we always observe on the solar circumference must also exist on the disk of the rotating Sun, tho concealed by its brilliant light. If we photograph the spectrum of the disk, we find the dark H and K lines of calcium to be brightly reversed in irregular patches, which are most extensive in regions surrounding sun-spots. To photograph the forms of these luminous clouds of calcium vapor (the flocculi), we set the H or K line on the camera slit of the spectroheliograph, and move this instrument slowly across the solar image. A series of photographs made in this way will provide the means of studying the structure and changes of the calcium vapor at different levels in the solar atmosphere.

Thus, aided by laboratory experiments with home-made apparatus for the interpretation of the solar results, the beginner should be fairly started in the field of astrophysics. Later, if he should wish to extend his equipment, he can acquire instruments powerful enough to permit the photography of solar vortices, and the study of the solar rotation, the pressure and motions in the solar atmosphere and the magnetic fields in sun-spots.

A brilliant Sun shines overhead, and the air is fragrant with the odor of orange blossoms on this February afternoon in Southern California. Yet I am forcibly reminded as I write these lines of a dark winter's day in Chicago some thirty-five years ago. I was reading "The Amateur Mechanic's Workshop," and even now I can feel the thrill of excitement which came with the sudden resolve to follow the example set in the book. The young mechanics of an earlier volume had begun the construction of a workshop, which was fully described and illustrated. Why should I not build one myself? The snow lay deep on the ground, and weeks of winter were yet to come. Clearly it was too soon to begin work out-of-doors. But the resolve had been kindled, and its impulse would not be quieted. I could already see the shop completed, with its long benches equipped with vises and tools, and my recently-acquired lathe (which had a small slide-rest, and would actually turn metal!) standing in the place of honor. Indeed, the lathe seemed suddenly to have acquired an overhead attachment for driving milling cutters and other accessories resembling those pictured in the books of Holtzapfel and other English authorities of the day. I could hear in imagination the hum of a small steam-engine, the castings for which had arrived on Christmas Day, and see it driving the cutters in the pleasantest manner in the world!

Surely such a dream must come true, snow or no snow. So I at once began work on the scale drawings, trudged thru the snow with my small sister and brother to the lumber-yard, and invested my slender savings in water-soaked 2 x 4's. Hauling these home on our sled was a heavy task, but when they were finally there we lowered a rope from the narrow window of a dark and lofty attic, and hoisted them up into its friendly shelter. Here the work of framing was pursued after school hours and on those joyful Saturdays, and before spring had really come the dismantled skeleton was lowered to the ground and the work of erection begun. Finally the shingles were all laid, and we looked with satisfaction upon our combined shop and laboratory. Tho only ten by fifteen feet in size, it gave us immense pleasure and prepared the way for later buildings of more ambitious kind.

Such memories have led me to write these pages. I have lost none of my respect for the books of my boyhood, or for the new ones which have been published since. But I hope that the actual experiences of a boy groping his way toward original research may have taught me something of the needs of others, and of practical methods of meeting them. Fortunately I have been able to enlist the collaboration of another amateur, Mr. Lorenzo Snow, whose acquaintance with present sources of optical and mechanical supplies is wide and varied. Mr. Snow will make working drawings of the instruments embodying our joint ideas, and describe the details of their construction. Our plan will be to utilize standard optical and mechanical parts, everywhere obtainable at very small cost from spectacle makers and dealers in machinists' supplies. In building the apparatus we do not intend to utilize the workshops of the Mount Wilson Observatory or others similarly equipped, but will rather depend upon the services of machinists and carpenters such as are found in every small town. In this way we hope to show how an amateur can have equally good instruments built almost anywhere, if he cannot adopt the far more satisfactory plan of making them himself. The papers will conclude with a series of experiments and observations designed to illustrate the use of the spectroscope and spectroheliograph and to serve as an elementary introduction to solar research. If they should succeed in convincing some serious beginner that the pleasures of his holiday hours may well be continued thru the whole of an investigator's life, they will accomplish the object for which they are written.

A SPECTROSCOPIC METHOD OF DETERMINING STELLAR PARALLAX[1]

By Walter S. Adams

The absolute magnitude of a star is defined as its apparent magnitude when reduced to unit distance, and may be calculated, when the distance is known, from the simple relationship

$$M = m + 5 + 5 \log \pi$$

In this equation M is the absolute magnitude, m the apparent magnitude, and π the parallax. It is evident that if some means exists by which M may be determined directly this expression will in turn provide a determination of the parallax.

The question whether the absolute magnitude of a star may not have a material influence upon the character of its spectrum is one which has been discussed to a considerable extent in recent years. It appears probable from investigations made at Mount Wilson that the intensity of the continuous spectrum is affected to a marked degree by the luminosity of the star; and such a result is rather to be expected when we consider that if two stars have closely the same type of spectrum but greatly different luminosities they probably differ greatly in size, in mass, and in depth of the atmospheres surrounding them. Such a marked difference in physical conditions would be almost certain to influence the intensity of the continuous spectrum, and we might even hope to find in the line spectrum of these stars certain variations in the intensity and character of such lines as are peculiarly sensitive to the conditions in the gases in which they find their origin.

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[1] Adapted from a series of papers published in the *Proceedings of the National Academy of Sciences*.

An attempt to detect such lines was made by Hertzsprung who concluded that the strontium line at λ 4077 gave some indication of varying with the absolute magnitudes of the stars in whose spectra it appeared. An independent and more extensive investigation by Dr. Kohlschütter of the Mount Wilson stellar spectra resulted in the discovery of two or three such lines, and the results of a preliminary application of the criterion of line intensity to the determination of absolute stellar magnitudes were published in 1914. Since that time the work has been extended greatly with the aid of additional observational material.

A prime essential to beginning such an investigation is an accurate classification of the stellar spectra into the several types. For this purpose a method has been used which was devised in large measure by Dr. Kohlschütter previous to his departure from Mount Wilson. It will be described briefly in the succeeding paragraphs, and the results obtained from it will then be utilized in a continuation of the discussion of absolute magnitudes.

Method of Classification

The material available for classification purposes consists of several thousand photographs of stellar spectra taken with a one-prism slit spectrograph and the sixty-inch reflector. About two-thirds of these spectra are of types succeeding Fo. On most of the photographs the region of spectrum in best definition extends from λ 4200 to λ 4900. It includes, therefore, the two hydrogen lines $H\gamma$ and $H\beta$, the important calcium line at λ 4227, and some of the most prominent iron lines in the entire spectrum. Since the hydrogen lines show a rapid decrease in intensity with the successive types F, G, K and M, and form by far the most important criterion in the determination of spectral type, accurate determinations of their intensity relative to other lines in the spectrum are essential. Accordingly several adjacent iron lines have been selected which show but a moderate change of intensity in these types, and estimates are made on an arbitrary scale, extending from zero to ten, of the differences in intensity between the hydrogen lines and this selected list. The calcium line λ 4227 is also compared with $H\gamma$ in the types Fo to G5, beyond G5 the differences becoming too great to provide satisfactory determinations. The list of pairs of lines finally adopted for classification purposes is given in Table I.

TABLE I

Line		Line	Element	Range of Type
Hγ	and	λ 4227	Ca	F1 to K5
Hγ	"	λ 4325	Fe	F5 to Ma
Hγ	"	λ 4351	Fe, Mg	F1 to Ma
Hγ	"	λ 4383	Fe	F1 to K5
Hγ	"	λ 4405	Fe	F5 to Ma
Hδ	"	λ 4072	Fe	G0 to Ma
Hδ	"	λ 4045	Fe	G0 to Ma

The scale of classification was adapted to the Harvard system by selecting a considerable number of stars for which Harvard determinations were available, and making estimates of the relative intensities of these pairs of lines in the stars selected. The values were then plotted against the average types of these stars, and smooth curves were drawn thru the several points. These curves provide the means of converting determinations of relative line intensity into determinations of spectral type. They are based upon stars of large proper motion alone, and the material may, therefore, be regarded as homogeneous in character.

To illustrate the use of these curves I have selected as examples the stars Groom. 3357, Piazzi 0^h130, Groom. 145 and Lal. 19022. The estimated differences of intensity for these stars, as determined from three photographs of their spectra, are given in Table II.

TABLE II

	4226/Hγ	4325/Hγ	Hγ/4351	Hγ/4383	Hγ/4405	Hδ/4072	Hδ/4045	Bands
Groom. 3357	0.0	−5.3	+7.0	+4.3	+7.0			
Pi 0^h130...		+3.7	+0.7		−1.3	+5.3	+2.0	
Groom. 145		+5.3	−2.0		−4.0	−0.2	−1.8	
Lal. 19022...		+6.3	−3.3		−5.0	−1.3	−3.3	1

With the aid of tables constructed from the curves we obtain the following determinations of spectral type from the separate pairs of lines:

						Mean	Probable Error
Groom. 3357...	F7	F7	F4	F6	F5	F6	±1.0
Pi 0^h130...	G7	G5	G6	G4	G5	G5	0.8
Groom. 145...	K1	K1	K3	K3	K2	K2	0.6
Lal. 19022...	K7	K7	Ma	K6	K6	K7	1.6

The average probable error of the determination of type for these four stars is ±1.0, and this is about the value obtained for several hundred stars classified in this way. It is evident that the accuracy will be least when the lines compared differ greatly in intensity, as in the types Fo–F9 and K5–Ma, and greatest when the lines are of nearly equal intensity.

This simple method of classification may be recommended as being rapid of operation, and free from the difficulties connected with the comparison of separate photographs with one another. It requires the establishment of a scale of relative intensity estimates by the observer, but this is a very simple matter when the range employed is small. To some extent the scale will be dependent upon the dispersion of the spectrograph employed since several of the lines used are compound in character. We have found, however, that with the single-prism spectrograph at Mount Wilson the same reduction curves may be used successfully for photographs on which the linear dispersion varies from 16 to 90 angstrom units to the millimeter at the center of the spectrum.

Determination of Absolute Magnitude and Parallax

The method of classification outlined above provides a means of securing a list of stars of closely similar spectral types. From among these stars pairs are then selected for which the absolute brightness is very different, and the relative intensities of the spectral lines are then examined carefully. To illustrate the method we may take as an example the two stars 61^1 *Cygni* and α *Tauri*. The measured parallaxes of these stars are $0''.31$ and $0''.07$, respectively, and their apparent magnitudes are 5.6 and 1.1. Their absolute magnitudes as computed from the equation

$$M = m + 5 + 5 \log \pi$$

are 8.0 and 0.4; that is, the luminosity of α *Tauri* is over 1100 times as great as that of 61^1 *Cygni*. A comparison of the spectra of the two stars side by side in a Hartmann spectro-comparator shows several points of difference. Of these two are most important. The calcium line at λ 4455 is very strong in 61^1 *Cygni* and relatively weak in α *Tauri*; and the strontium line at λ 4216 is weak in 61^1 *Cygni* and strong in α *Tauri*.

That this difference in behavior depends upon physical conditions in the stars and is not merely accidental is made almost certain by solar investigations. The line λ 4455 of calcium is greatly strengthened in the spectrum of sun-spots and increases in intensity with reduction in temperature. The line λ 4216 of strontium, on the other hand is an enhanced line, that is, stronger in the spectrum of the spark than of the arc, and is probably a high temperature line. It is very prominent in the spectrum of the Sun's limb when photographed at eclipses, and also in the upper chromosphere. Numerous other smaller differences between the spectra of *α Tauri* and 61^1 *Cygni* all point in the same direction; the low temperature lines strengthened in sun-spots are stronger in 61^1 *Cygni;* the enhanced lines are stronger in *α Tauri.* It has seemed preferable, however, for two reasons to use only these two lines in the absolute magnitude investigation. First, because they show the effect most markedly; and second, because they appear to be influenced but slightly by closely adjoining lines which blend with them.

After the behavior of the two lines λ 4216 and λ 4455 had been examined in a large number of stars and the systematic differences had been found to persist thru a wide range of spectral type the attempt was made to establish a numerical relationship between their intensities and the absolute magnitudes of the stars in which they occur. As in the case of Hγ and Hβ used for classification purposes, lines were selected near λ 4216 and λ 4455, with which the intensities of these lines were compared, the differences of intensity being estimated on a scale extending from zero to ten. The pairs of lines finally adopted for all of this work are as follows:

Line	Element		Line	Element	
λ 4216	*Sr*	and	λ 4250	*Fe*	(a)
λ 4455	*Ca*		λ 4462	*Fe, Mn*	(b)
λ 4455	*Ca*		λ 4495	*Fe*	(c)

For convenience of reference these pairs of lines will be designated in the future as (a) (b) and (c). The value (a) = —2, for example, denotes that λ 4216 is estimated to be two units fainter than λ 4250.

As soon as the estimates had been completed a number of the stars with well-determined parallaxes were selected, their absolute magnitudes were computed, and curves were constructed in which the observed differences of intensity for each pair of lines formed the abscissæ, and the absolute magnitudes the ordinates. The stars were divided into five groups according to spectral type and curves were drawn for each group. The groups are as follows:

Fo-F6; F7-G7; G8-K4; K5-K9; M.

The curves are so nearly straight lines in the case of the first three of these groups that straight lines have been adopted, the constants being derived by least square solutions. In the K5-K9 group the curve for (a) is a straight line but not for (b) or (c). It is probable that there are no straight lines in the M group, but this is very uncertain. The significance of a straight line is, of course, that the intensity of the line varies uniformly with the absolute magnitude.

The most serious difficulty in the construction of these curves is the scarcity of parallax determinations on stars of high luminosity. Parallax observers have confined their attention almost wholly to stars of large proper motion which promise to yield large parallaxes. With the aid, however, of the Yale observations on the very bright stars, and some most valuable determinations by Mr. van Maanen of the parallaxes of certain stars of small proper motion a number of stars of very high luminosity were selected upon which the lower portions of the curves could be based. Particularly in the cases of the K5-K9 and the M groups these portions of the curves are still most uncertain, and must be adjusted with the aid of additional parallax observations when they become available.

The list of formulæ derived for the several groups is given in Table III. The equations are from my own observations. A similar list, in which the constants differ slightly, has been obtained from the determinations of Miss Burwell, who has carried out a complete series of estimations of the line intensities in these stars. In the formulæ M is the absolute magnitude, and Δ the estimated difference of intensity for each of the pairs of lines.

TABLE III

	(a)	(b)	(c)
Fo–F7	$M = -1.9\ \Delta + 5.2$	$M = +2.0\ \Delta + 3.3$	$M = +2.8\ \Delta - 2.6$
F3–G7	$M = -1.4\ \Delta + 4.9$	$M = +2.0\ \Delta + 3.3$	$M = +2.8\ \Delta - 2.6$
G3–K4	$M = -1.6\ \Delta + 4.7$	$M = +1.6\ \Delta + 5.1$	$M = +2.3\ \Delta - 0.3$
K5–K9	$M = -1.8\ \Delta + 5.0$	Curve	Curve
M (low luminosity)	$M = -1.5\ \Delta + 6.9$	Curve	Curve

The equation and curves in the case of the M stars are applicable only to the stars of low luminosity. In the case of the F0-F7 stars it is doubtful whether the equations given, which for (b) and (c) are the same as in the G group, are other than rough approximations. The enhanced lines in the early F stars are normally so prominent that it is not surprising that the method begins to break down at this point.

To illustrate the use of the formulæ and curves we may select as illustrations a few stars of different spectral types and magnitudes. These are collected in Table IV. The classification is from Mount Wilson determinations.

TABLE IV

STAR	Mag	Type	Δ			M				Parallax	
			(a)	(b)	(c)	(a)	(b)	(c)	Mean	Comp.	Obs.
Pi $10^{h}96$...	7.6	F5	−0.7	+0.7	+3.0	+ 6.5	4.7	5.8	5.7	+0".04	+0".04
Sun.......	....	G0	−0.5	+0.5	+3.0	+ 5.6	4.3	5.8	5.2	......	......
Lal. 38287.	7.2	G5	−1.8	+1.5	+3.5	+ 7.4	+6.3	+6.2	7.3	+0.10	+0.09
α Arietis...	2.2	K0	+2.5	−2.4	+0.2	+ 1.0	1.3	+0.2	0.8	+0.05	+0.09
α Tauri....	1.1	K5	+3.0	−2.0	+0.5	− 0.4	+1.9	+0.5	0.7	+0.08	+0.07
61^{2} *Cygni*..	6.3	K8	−1.8	+5.8	+7.7	+ 8.2	9.3	8.9	8.8	+0.32	+0.31
Groom. 34.	8.2	Ma	−2.2	+6.8	+9.2	+10.2	10.5	10.4	10.4	+0.28	+0.28

The parallaxes are computed from the absolute magnitudes by the formula, to which reference has already been made,

$$5 \log \pi = M - m - 5$$

The results are given in the next to the last column of the table, and the measured parallaxes in the final column.

It is evident that in the case of the stars whose absolute magnitudes, as computed from the measured parallaxes, have been used in the derivation of the relationship between line intensity and absolute magnitude, the mean values of the magnitude will necessarily be identical with those derived from the formulæ. The agreement of the measured and the computed parallaxes of the individual stars, however, serves as important evidence bearing on the validity of the method.

In two tables published in detail in the *Proceedings* are collected all of the stars with measured parallaxes equal to or exceeding

+0″.05 for which we have spectral observations. The first contains the stars used in the derivation of the curves; but in the second the results are quite independent and serve as a rigorous test of the value of this means of computing stellar parallaxes. The average deviation, taken without regard to sign, between the observed and the computed values for the stars of the first table is 0″.024; for those of the second table it is 0″.026. The deviations are distributed as follows:

First Table.....0—0″.02 (37), 0″.02—0″.04 (16), >0″.04 (5)
Second Table....0—0″.02 (43), 0″.02—0″.04 (11), >0″.04 (12)

There is but one deviation exceeding 0″.1 in the 124 stars contained in the two tables. There seems to be no marked systematic difference between the observed and the computed parallaxes; the former average somewhat larger, but this is due mainly to a few large discrepancies.

There are 25 stars with measured negative parallaxes for which we have made spectrum determinations. The largest value for any one of these stars as computed from the line intensities is +0″.08; the average value for all is +0″.03. The spectrum method, of course, gives no negative parallaxes.

It seems reasonable to conclude from these results that the method of computing absolute magnitudes and parallaxes from the variation of the intensities of lines in stellar spectra is capable of yielding results of a very considerable degree of accuracy. Especially in the K and M type stars of low luminosity the line variations are so great that such stars may be recognized from a mere inspection of the spectrum. Stars, for example, like 61 *Cygni*, Groom. 34 and Krüger 60 bear very evident marks of their intrinsic faintness in the remarkable intensity of the low temperature calcium lines in their spectra.

An important gain in the value of this method of determining stellar magnitudes and distances should result from an increase in the number of measured parallaxes of bright stars of small proper motion. Such stars will on the average prove to be very luminous, and as already stated the portion of the curves connecting line intensity with absolute magnitude is subject to much more uncertainty in the case of the very high luminosity stars than in any of the others. It is probable that after such a revision has been made the method will find its most important application as a means of distinguishing these giant stars in the stellar system.

Mount Wilson Solar Observatory,
January, 1916.

THE DIURNAL VARIATION OF THE REFRACTION.

By R. H. Tucker.

The question of diurnal variation in the amount of the atmospheric refraction is not entirely a new one. But there are still points of novelty in its consideration, and the references to the subject are mostly rather vague, with but little data of definite value. It has been conceded that each observing station may require special treatment, and this is especially likely for one of the elevation of Mount Hamilton. Every observation of a standard star, made here, has been reduced in such a manner as to present, in the derived value of the latitude, a contribution to the refraction correction. For many years these values agree in giving a smaller value of the refractions during the night observations, than that of the Poulkova constant, which is already considerably smaller than that of Bessel, long adopted for meridian work in the large observatories of the world.

In the preliminary reductions of the fundamental work, carried on here from 1905 to 1908, it became evident that the value of the refraction in daytime observing was different from that of the night hours, and the subject was thoroly discussed, for the years 1905 and 1906 in *L. O. Bulletin* No. 231, published in April, 1913.

The variation there derived was based upon the combination of the extreme southern stars, and north stars at lower culmination, in two programs, differing twelve hours in right ascension. The separate stars, up to 80° zenith distance south, and 83° north, were also treated individually, for comparison of the effect of spectral type. No dependence upon type, or magnitude, or zenith distance, or position north or south, could be traced in the various combination; which agree in giving a total difference between day and night refractions, which is in the neighborhood of 0″.5 tan. Z. D., or about one per cent. of the total refraction.

The observations of those years were planned for every hour of the day and night, but some gaps unavoidably occurred in the months of bad observing weather. Also, since the principal object at the time was considered to be the observation of the azimuth, and the derivation of the position of the meridian mark and its variations, the zenith distances were not always observed at the transit near noon, the unsteadiness of the stars being so great that the results were likely to be very uncertain. Since the development of the diurnal change in the refraction, the noon observations are necessary to fill in the curve of the variation in daytime, and these observations will be made in this year, if weather conditions permit The original series gives determinations extending from three and a half hours before sunset, to over four hours following sunrise. *Polaris* and *β Ursæ Majoris* can be observed at noon; but even the brightest stars can not be observed in full daylight at low altitudes, where the density of the atmosphere renders the absorption too great for their visibility. I commonly reckon that the brightness is reduced by five magnitudes at the zenith in daylight, another magnitude at zenith distance 70°, and over two magnitudes at 80°. The unsteadiness at even moderate zenith distances adds greatly to the difficulty of making daytime observations, for the faint object actually disappears entirely under bad conditions. The full program of stars extended an hour beyond the daylight limits mentioned above, but the zenith distances of all but ten stars were too small for profitable discussion of refraction errors. The present series will include night observations, those in full daylight, and the necessary check determinations upon other stars near sunrise and sunset Meantime, a test has been made of the earlier observations of *Polaris* in combination with *β Ursæ Majoris*, both of which transit near the same time, at opposite culminations. These two stars are of similar spectral type, tho the zenith distances are not great enough to introduce any sensible atmospheric dispersion. Observations of *a Andromedae* were always made in the same series, which gives a check value of the instantaneous latitude, independent of errors of nadir reading and of the Variation of Latitude. From the respective probable errors, I estimate such a determination of the zenith point as of three times the weight of nadir direct.

The combination of *Polaris* U. C. and *β Urs. Maj.* L. C. gives a difference of tangents of zenith distance = 1.23, which is of course very small in comparison with the single stars at low altitudes, which gave tangent factors six or more times as large; doubled again in the combination of north and south stars, upon which the final result was based. The combination also of four circumpolar stars, of declinations 60° to 70° gave differential tangent factors, at the two culminations, of from 4 to 8, for a check computation of the variation. In any of the direct comparisons the declination errors are included, but these are fully eliminated in the comparison of day and night results. Thus, the combination above described gives the following corrections to the Poulkova Refractions:

21 Daytime observations,	+0″.27	tan	Z. D.
19 Night "	+0 .17	"	"
Difference (D-N)	+0 .10	"	"

Two daytime differences, nearly balancing in effect, were excluded from the computation, as their respective residuals exceed four times the probable error of a single value.

The combination of *Polaris* L. C. and *β Urs. Maj.* U. C. is not nearly as strong, as the difference of tangents is only 0.59, and should have one-fourth the weight of the first combination, depending upon the squares of the respective factors. The probable error of a single determination of the refraction correction in the first, is one-third that of the second combination. This last gives the corrections to the Poulkova Refractions:

17 Daytime observations,	+1″.44	tan	Z. D.
17 Night "	+0 .42	"	"
Difference (D-N)	+1 .02	"	"

The weighted mean of I and II is, D — N = +0.″28 tan Z. D. from 76 series.

During the year 1905-06 a full 100 transits were obtained of *Polaris*, and the accompanying stars, but the zenith distance observations were omitted for a portion of the transits. This weighted result is in fair accord with the much stronger value of the discussion in the published Bulletin. There is a slight progressive change during the night, and a very rapid change near sunrise and sunset; the mean result for daytime falls within two hours of these two epochs and accordingly the full effect of the change does not appear in the mean differences. It has given a better illustration of the effect to reckon from sunrise and sunset, rather than from noon, as the length of the day changes so greatly with the seasons; and the effect may be believed to be due to the action of the Sun, while above the horizon, in changing the refractive influence of the air strata from that computed for the temperatures given by our thermometers at the surface of the Earth. The actual recorded temperatures, and their changes up or down, during the hours of observation, were shown, in the earlier discussion, to have no direct influence upon the general result.

To illustrate the conformity of the variation at different zenith distances, the results of the full list of stars in the two programs are tabulated below. The greater part of all meridian work is done at night, and the discussion of daytime refraction corrections has practical value only in connection with fundamental work, which must be carried thru the twenty-four hours. In the differential determination all other sources of error have been quite completely eliminated. In the original reductions, the graduation errors measured for all the divisions employed (*L. O. Pub.* Vol. X), have been applied, but even these corrections are eliminated in the comparison. For south stars, the errors of the standard declinations adopted enter the direct determination of the refraction correction, but are eliminated in the differential comparison. For circumpolar stars it is theoretically possible to eliminate the errors of assumed declinations, by observing both the culminations; but, practically, we have to deal with two determinations under varying conditions, with different nadir readings, graduation errors and widely different zenith distances at the two culminations. The only safe course is to arrange the reduction of the observations so as to eliminate every error except the accidental errors of observation, which are diminished in effect as we increase the number of determinations, up to the point of practical efficiency. Astronomical literature bears the burden of numerous discussions, these days, assuming the failure of methods of observation, due to accidental refraction errors, to sluggish levels, and to various defects in the instruments employed. In contrast, we are here dealing with a practical source of error, the effect of which can be determined and accounted for.

Diurnal variation at all Zenith Distances (D-N).

4 South	Stars,	Z. D.	76°.7,,	correction,	+0″.28	tan	Z. D.
14 ΔT	"	"	41 .1	"	+0 .17	"	"
4 Z	"	"	1 .4		....		
5 U. C.	"	"	25 .2	"	−0 .20	"	"
5 L. C.	"	"	78 .2	"	+0 .32	"	"
Polaris		"	52 .6	"	+0 .58	"	"

The mean, with weights proportional to the tangents is +0″.30 tan Z. D.: and with weights proportional to the squares of the tangents it is +0″.31 tan Z. D. The full difference, with daylight observations extended to noon, will be considerably larger.

The daytime observations, besides the difficulty of making them, have very much larger accidental errors than those made under the favorable conditions generally prevailing at night. The rapidly moving south stars are more difficult to see than the comparatively slow moving north stars, and the atmospheric glare facing south makes a very considerable difference. Thus, second magnitude stars are often impossible at moderate zenith distances south, while north stars of similar brightness and altitude are comparatively easy to observe. In general, from experience at three other important observing stations, the daytime conditions at Mount Hamilton can be described as the worst of all the stations, while night conditions are often the best experienced at any of them.

It is a curious anomaly, here, noticed generally in daytime, that the stars south of the zenith are comparatively steadier than those north, when a southerly wind prevails; and the reverse conditions are noticed when a northerly wind prevails.

March 15, 1916.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1916.

By Malcolm McNeill.

Phases of the Moon, Pacific Time.

New Moon.....	May 1st,	9h 29m	P.M.	First Quarter...	June 8th,	3h 59m	P.M
First Quarter....	" 10th,	12 47	A.M.	Full Moon......	" 15th,	1 42	P.M.
Full Moon......	" 17th,	6 11	A.M.	Last Quarter....	" 22d,	5 16	A.M.
Last Quarter....	" 23d,	9 16	P.M.	New Moon.....	" 30th,	2 43	A.M.
New Moon.....	" 31st,	11 37	A.M.				

The Sun reaches the summer solstice on June 21, 10^h 24^m A. M. Pacific time, and then begins to move southward.

Mercury during May is in the best position of the year for evening observation. On May 1st it sets more than an hour and a half after sunset, and this interval increases until near the middle of the month, when it is only a few minutes less than two hours. Greatest east elongation is reached on the morning of May 12th. Its apparent distance from the Sun is then 21° 43′, an average distance for a greatest elongation. After passing greatest elongation the planet approaches the Sun, so that during the last week in May it is too near for naked eye view. On June 5th inferior conjunction is reached and the planet becomes a morning star. The distance between the Sun and planet rapidly increases and greatest west elongation is reached on the evening of June 29th. The elongation is of average size, 21° 52′; but the planet is a considerable distance south of the Sun, partly because it is in the southern part of its orbit, and the interval between the rising of the planet and sunrise is but little more than one hour, so that it is in rather poor position for naked eye view. At the beginning of May the planet is about twice as bright as the ordinary first magnitude star, but it grows fainter and by the time it is too near the Sun for observation toward the end of the month it is about as bright as the pole star.

Venus, except for the Moon, is by far the most conspicuous object in the evening sky until near the end of June. On May 1st it does not set until nearly 11 P. M., not quite four hours after sunset; but having passed its greatest east elongation near the end of April, the Sun and planet are apparently drawing nearer together. On June 1st it remains above the horizon until nearly three hours after sunset. This interval diminishes to less than two hours by the middle of the month, and by the end of the month the two bodies are nearly in conjunction, too near for naked eye view of the planet. On May 27th, halfway between greatest elongation and inferior conjunction, *Venus* reaches its greatest brilliancy, being then bright enough to be seen in full daylight, altho not very easy to detect unless one knows just where to look for it. Its stellar magnitude is then —4.2, that is it is more than one hundred times as bright as the average first magnitude star. Its motion among the stars is eastward until June 11th, about 26° since May 1st, from the eastern border of *Taurus* into *Gemini* being at the latter date a few degrees south of *Castor* and *Pollux*. It then begins to retrograde, move westward, and at the end of the month has gone back about 7°; but during the turning it has also moved southward so that on June 30th it is over 6° due south of the position it occupied on May 21st. The relative motions of *Venus* and *Saturn* are very interesting, and afford a very good illustration of direct and retrograde planetary motion. *Saturn* during the two months' period moves about 6° direct, that is, eastward. The two planets are twice in conjunction: the first time on the night of May 23-24, when *Venus* passes *Saturn* 3° 25′ north of the latter. The relatively greater eastward motion of *Venus* soon slackens, and after it reaches a position about 4° east of *Saturn* in early June, it begins to approach again, but meanwhile swings a considerable amount to the southward so that when they reach the second conjunction on June 22nd *Venus* is not quite 1° south of *Saturn*, having nearly encircled the latter in the month elapsed since the first conjunction.

Mars is still in pood position in the western sky for evening observation altho it has ceased to be a very conspicuous object; however it is still easily identified. On May 1st it is about twice as bright as an average star of the first magnitude, but by the end of June it is about half way between a first and second, that is, twice as bright as the pole star. On May 1st it set shortly before 2 A. M. and at about 11 P. M. on June 30th. During the two months it moves about 27°

eastward and 12° southward from *Cancer* to the eastern part of *Leo*. During the latter half of May it is near the first magnitude star *Regulus, α Leonis,* passing that star on May 24th from west to east and about 1° north.

Jupiter is a morning star almost too near the Sun for naked eye view on May 1st as it then rises less than an hour before sunrise; but the interval increases rapidly so that by the end of June it rises shortly after midnight. It is in the eastern part of *Pisces,* moving 11° eastward and 4° northward during the two months.

Saturn is still in fair position in the western sky in the evening, but is gradually drawing near the Sun. On May 1st it remains above the horizon until about $11^h\ 30^m$ P. M., but at the end of June it sets a few minutes after 8 P. M., only a little more than a half hour after sunset, and therefore too near for naked eye view. It is in the constellation *Gemini* south and west of *Castor* and *Pollux* and during the two months moves about 7° eastward among the stars. The relative motions of *Saturn* and *Venus* have already been noted.

Uranus rises shortly before 2 A. M. on May 1st and shortly before 10 P. M. on June 30th. It is in the constellation Capricorn and moves slowly eastward until May 24th and then begins to retrograde, but the whole motion is about equal to the apparent diameter of the Moon. No bright star is near it, but the third magnitude, δ *Capricorni,* is about 3° east and 1° south of the planet.

Neptune is in the western sky in the evening in the constellation *Cancer.*

(EIGHTY-SIXTH) AWARD OF THE DONOHOE COMET-MEDAL

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Mr. John E. Mellish, of Cottage Grove, Wisconsin, for the discovery of an unexpected comet on February 10, 1915.

COMMITTEE ON THE COMET-MEDAL:

W. W. CAMPBELL,
R. H. TUCKER,
HEBER D. CURTIS.

(EIGHTY-SEVENTH) AWARD OF THE DONOHOE COMET-MEDAL

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Mr. John E. Mellish, of Cottage Grove, Wisconsin, for the discovery of an unexpected comet on September 13, 1915.

COMMITTEE ON THE COMET-MEDAL:

W. W. CAMPBELL,
R. H. TUCKER,
HEBER D. CURTIS.

(EIGHTY-EIGHTH) AWARD OF THE DONOHOE COMET-MEDAL

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Mr. C. J. Taylor, of Cape of Good Hope, South Africa, for the discovery of an unexpected comet on December 2, 1915.

COMMITTEE ON THE COMET-MEDAL:

W. W. CAMPBELL,
R. H. TUCKER,
HEBER D. CURTIS.

NOTES FROM PACIFIC COAST OBSERVATORIES.

THE PRODUCTION OF CERTAIN BANDED SPECTRA IN THE ELECTRIC FURNACE.

Experiments have recently been made with the electric furnace to obtain evidence on the origin and observe the behavior at various temperatures of the banded spectra which have been ascribed by Fowler and others to titanium oxide, magnesium hydride and calcium hydride, respectively. All of these bands occur in sun-spot spectra, and the probability that the first named, the "Antarian bands," are due to titanium oxide has been taken as indicating the presence of oxygen in the Antarian stars as well as in the Sun.

It was noted in a previous investigation that these Antarian bands do not appear when titanium is vaporized in the furnace in vacuum. The present work was undertaken to see if the presence of oxygen would bring out the bands in the furnace as it does in the arc. Tests with air in the furnace chamber at one-half atmosphere and at atmospheric pressure did not give the bands. It seemed, however, that this might indicate simply a lack of oxygen in the furnace tube due to its carbon immediately using up the oxygen of the contained air, there being little circulation thru the horizontal tube. The windows of the furnace chamber were therefore removed, and a plentiful supply of air was introduced directly into the tube by means of a silica tube attached to a bellows. The band spectrum then appeared with great intensity. Altho pure oxygen has not yet been tried in the furnace, it is fairly certain that the banded spectrum is brought out by the oxygen of the air, since it has been found with the arc that an atmosphere of nitrogen suppressed the bands.

When the bands were made strong in the furnace, the line spectrum, at least in the yellow and red region under examination, was rendered very faint, as if all the titanium vapor were turned into the oxide, and this gave the band spectrum alone. No decided change in temperature was evident when air was used in the tube. It may be noted that this use of the furnace produces what may be regarded as a very hot flame spectrum, since the metallic vapor in the tube is raised to a high temperature and the oxygen is then supplied for the flame effects.

Experiments with the furnace in vaporizing magnesium and calcium in an atmosphere of hydrogen confirms the arc results as to the effect of hydrogen in bringing out the bands ascribed to the hydrides of these elements. Both sets of bands can be produced faintly with the furnace pumped out, but the spectrum of the "tube-arc" has shown that considerable hydrogen is present under such conditions, probably occluded by the graphite tube. The use of hydrogen in the furnace chamber at different pressures and temperatures gave rather variable results until the method was adopted of passing a stream of hydrogen thru the furnace tube during the exposure, the pressure in the chamber being maintained at from 10 to 20 cm. of mercury. The bands were then obtained moderately strong without, however, any perceptible weakening of the line spectrum. The best defined bands in these bands are at λλ 4845, 5211, 5261 for magnesium and λλ 6382, 6389 for calcium. A temperature not higher than 2200° C. seemed to be most favorable for them. At 2500° the bands were weaker and were liable to appear in absorption, as if they were given by the cooler vapor near the end of the tube.

These results indicate that the strengthening of the titanium, magnesium, and calcium bands by the presence of oxygen or hydrogen, observed in the arc experiments, does not depend on an alteration of the arc discharge by the surrounding gas, and point to the formation of a compound at moderate temperature in each case.

Arthur S. King.

The Magnesium Line λ 4571 in the Electric Furnace.

In some experiments made in 1904 with a furnace consisting of a carbon tube tested by an arc playing on the outside, I observed a very high relative intensity of the Mg line λ 4571.275, one of the weaker arc lines, when magnesium was vaporized inside the tube. A recent study of the magnesium spectrum in the tube resistance furnace at different temperatures has confirmed this observation and shows a striking contrast between this line and neighboring lines of magnesium. At 1950° C., λ 4571 is of nearly the same intensity as λ 5184, the strongest member of the *b* group, while the strong arc lines λλ 4352 and 4703 have not appeared. At temperatures above 2200°, while the arc lines are gradually developing λ 4571 is liable to appear in absorption, its tendency to reverse being comparable with that of the calcium line λ 4227, λ 4571 remains narrow, however, and when in absorption does not show distinct emission wings in the photographs thus far made, indicating that the line may not be given by the hot vapor in the middle of the tube. At any rate, a decided strength for λ 4571 seems a clear indication of a low temperature condition.

ARTHUR S. KING.

THE SPECTRUM OF NOVA GEMINORUM NO. 2, FEBRUARY, 1916.

A photograph of the spectrum of Nova *Geminorum* No. 2 taken on the nights of February 12th and 13th with a total exposure of nine hours shows that it has remained essentially unchanged during the past year. The spectrum is of the definite Wolf-Rayet type with bright hydrogen lines and an exceedingly prominent bright band at λ 4686. Several other Wolf-Rayet bands are present. The continuous spectrum is very strong.

WALTER S. ADAMS.
FRANCIS G. PEASE.

TWO SPECTROSCOPIC BINARIES.

	Mag.	Spectrum	R. A. 1915	Dec. 1915	Range in Velocity, km
Boss 4138 . . .	5.7	F8p	16h 11m.5	+34° 5′	Composite
5906 . . .	5.0	A2	23 14 .1	+41 19	−86 to +10

The first of these stars is the brighter component of the well-known double star σ *Coronae*. On two of the spectrograms the spectra of both components appear and are very similar in character. A relative displacement between the components of nearly 140^{km} is indicated by one of these photographs.

WALTER S. ADAMS.

AN INTERESTING CASE OF TWO STARS OF COMMON MOTION.

In a previous number of this *Journal* reference was made to the extraordinary radial velocity of the large proper motion star A. Oe. 14320. A second star with the same proper motion is distant from it 5′ in declination. Two observations of the spectrum of this second star have now been obtained. The results for the pair are as follows:

	Mag.	Spectrum	R. A. 1915	Dec. 1915	μ	V, km
A. Oe. 14320	9.2	G4	15h 5m.5	−15° 57′.5	3″.76	+295
A. Oe. 14318	9.6	G5	15h 5m.5	−16° 2′.5	3″.76	+307

The photographs were taken with low dispersion and the accuracy of the determinations is relatively low. The radial velocities of the two stars may, therefore, be considered as equal. The absolute parallax of the stars is $+0''.035$ according to a determination by Russell. Hence their distance from one another is about 8600 times the radius of the Earth's orbit, or about one-thirtieth of the distance to α *Centauri*. We have, therefore, the interesting result that two stars separated from each other by an interval of the order of stellar distances are moving in precisely the same direction at a rate of about 580^{km} per second.

WALTER S. ADAMS.

THE COLORS OF FIFTEEN VARIABLES IN M 3.

We know from Bailey's work that in length of period and nature of light variation the variable stars in the globular cluster Messier 3 are closely similar to the short period Cepheids found outside the clusters. From recent measures of photographic and photovisual magnitudes it now appears that the spectra of these stars are also similar to the spectra of the non-cluster variables of analagous periods. The following values, which indicate the color at or near maximum light,. are given only to tenths since they are subject to some revision when the study of the cluster is completed.

No. Var.	Photovisual Magnitude	Color Index	No. Var.	Photovisual Magnitude	Color Index
22	15.2	+0.2	71	15.2	+0.1
43	15.2	+0.1	85	15.3	+0.0
44	15.3	+0.2	98	15.3	+0.2
56	15.3	−0.2	99	15.2	+0.1
61	15.1	−0.1	107	15.2	+0.3
65	14.9	+0.0	121	15.1	−0.2
70	15.2	−0.0	128	15.2	−0.1

The average photovisual magnitude at maximum is 15.20. The average color index is +0.05, corresponding to spectral type A1, which is practically identical with the average spectral type at maximum of the Cepheids with periods less than a day. If we assume that, in keeping with other Cepheids, the average absolute brightness of these variables in Messier 3 is not fainter than zero magnitude at maximum, then we derive at once that the parallax of the cluster is less than 0″.0001.

One of the brightest stars in the cluster, No. 95, is a variable of a totally different type. The range is small. Bailey was unable to determine the period and suggested that it might be an Algol variable. The new magnitude measures show the star to be very red; it may, therefore, be a variable of long or irregular period. Many such stars are known to be of high luminosity.

HARLOW SHAPLEY.

A LOW BAROMETER RECORD.

An extremely low barometer was recorded at the Lick Observatory on Thursday, January 27, 1916. The minimum was recorded at 2:20 P. M., when the actual reading, corrected for scale and temperature, was 24.60 inches. This, reduced to mean sea-level and corrected altitude, becomes 28.87 inches.

WARREN K. GREEN.

THE WAVE-LENGTH OF THE GREEN NEBULAR LINES N_1 AND N_2.

In order to reduce our 3-prism photographs of the spectra of the more brilliant "bright-line" nebulæ, it was necessary to construct the curve of the relationship between the wave lengths of the lines and the micrometer readings on the lines. We photographed the spark spectrum of titanium and the tube spectra of hydrogen and helium on the same plate, for this purpose. We found at once that there was an error in Runge and Paschen's wave length of the strong helium line in the green, 5015.73 A. Our curves based upon the iron and titanium spectra demanded a wave length of about 5015.85 A for the helium line. Upon examining the literature of the helium spectrum, we noted that the interferometer determinations of the position of the helium line in question, by Rayleigh and by Eversheim, 5015.856 and 5015.857, respectively, are in good agreement with the indications of our curves. Inasmuch as Wright's determination of the wave lengths of the two green nebular lines near 5007 A (N_1) and 4959 A (N_2)—the determination of greatest weight yet made—was based in part upon Runge and Paschen's erroneous position of the green helium line, we decided to use our efficient equipment in a new determination of the wave lengths of N_1 and N_2.

Our determination is based upon the measures of 19 spectrograms: four of the nebula N. G. C. 6572, five of N. G. C. 7027, and 10 of the *Orion* nebula. The comparison spectra of hydrogen and helium were impressed at frequent and regular intervals upon all of the plates; and on a few of the plates the spark lines of titanium at 4981 and 4991 A were used along with those of hydrogen and helium in fixing the positions of the nebular lines.

We have assumed as the wave-length of the comparison lines the following: for the hydrogen line $H\beta$, W. E. Curtis's value, 4861.51 A; for helium, the mean values of the interferometer measures by Rayleigh and by Eversheim, 5015.86 and 4922.11 A; and for titanium, Kilby's values.

On all of our plates the nebular lines N_1, N_2 and $H\beta$ are recorded. It was assumed that the normal wave-length of the

Hβ line is identical in the nebular and comparison spectra and that the observed displacements of the Hβ nebular line were due to the relative radial velocities of the nebulæ and observer. The measured positions of the nebular lines N_1 and N_2 on each spectrogram were then corrected for the radial velocity indicated by the Hβ nebular line on the same spectrogram. Each plate was measured by Mr. Campbell, Mr. Moore and Miss Hobe. The weighted means of their determinations from the nineteen spectrograms are

N_1	N_2
5007.023 ±.007	4959.080 ±.009 (Rowland system).

In the following table we have collected the results obtained by the modern observers. The values attributed to Wright are from his recent re-reduction of his 1901 observations upon the basis of Rayleigh's and Eversheim's wave-lengths of the helium lines.

Wave-lengths of the Nebular Lines N_1 and N_2.

	N_1	Wt.	N_2	Wt.
Keeler	5007.05 ±.03	1	4959.17 ±.04	¼
Hartmann	7.04	¼	9.17	¼
Wright	6.993 ±.012	2	9.095 ±.013	2
Campbell & Moore	7.023 ±.006	3	9.080 ±.008	3
Mean	5007.018		4959.094 (Rowland sys.)	

The weights which we have assigned to the results by different observers are those which in our judgment appear to be a fair estimate of their relative merits, after a careful consideration of the methods of observation, and of the number and quality of the individual measures.

We recommend that the above weighted mean values be rounded off to

N_1	N_2
5007.02	4959.09 (Rowland system).
5006.84	4958.91 (International system).

A detailed account of the investigation will appear in *Lick Observatory Bulletin*, No. 279.

W. W. CAMPBELL,
J. H. MOORE.

IS THE CRESCENT FORM OF VENUS VISIBLE TO THE NAKED EYE?

Joseph Offord has recently published in the *Journal of the Royal Asiatic Society* an interesting paper on the deity of the crescent *Venus* in ancient western Asia, in which he upholds the thesis that the crescent form of *Venus* was well known to the early inhabitants of Mesopotamia. He quotes from cuneiform literature as follows:

> "If on the right horn of *Venus* a star is visible, you will have good crops in the land;
> When upon the right horn of *Venus* a star is not visible, the land will bear many misfortunes."

There are other passages referring to the horns of *Venus*.

I find it difficult to believe that any one has ever seen the crescent form of *Venus* without telescopic aid, and I am inclined to think the explanation of the early references to the horns of *Venus* rests upon a lucky guess, as in the case of the two little satellites of *Mars*. Dean Swift described the latter quite accurately, as is well known, and his description undoubtedly rests upon a lucky guess. The ancients had the crescent form of our Moon before them every month as an example. *Venus* is the object next in brightness to the Moon, and of the many guesses which were probably made as to the form of Venus, the crescent would probably be the favorite and prevailing one.

The clear air of Mesopotamia has been suggested as of great assistance to the naked eye in seeing the crescent form of *Venus*. I am inclined to think that the greater brilliancy of the planet resulting from abnormally pure atmosphere would be a hindrance to the eye, and that the chances for seeing *Venus* as a crescent would be improved if the brilliancy were reduced by a thin absorbing medium of cloud or haze. Likewise the extreme steadiness of the air, which the observers in Mesopotamia and elsewhere were undoubtedly favored with at times, does not seem to me to be a vital factor: the twinkling effect when one sees *Venus* in a telescope under merely average atmospheric conditions involves motions of

Venus which are only a minute fraction of the angular diameter of the planet's image.

Even when *Venus* is exactly between the Earth and the Sun, and with the Earth near the perihelion, the angular diameter of *Venus* is only a few seconds greater than one minute of arc, and at such times *Venus* can not be seen at all by the naked eye. When the diameter of *Venus* is a minute of arc, and even somewhat less than a minute of arc, the planet is always close to the line joining the Earth and the Sun, and therefore must be looked for in a brilliant glare of sunlight. What is the advantage of a sky of Mesopotamian purity under such conditions? When the planet is far enough from the Sun in angular distance to let it be seen in the dark night sky, the angular diameter of the planet is always a great deal less than one minute of arc, perhaps always less than a half minute of arc. I think that the experiments with the human eye are conclusively in favor of the inability of the eye to define the form of a brilliant light source under those conditions.

For the reasons quoted above, I am inclined to attribute the ancient description of *Venus* as a crescent to pure lucky guess and coincidence, probably made under the influence of a crescent Moon.

W. W. CAMPBELL.

THE TOTAL SOLAR ECLIPSE OF JUNE 8, 1918.

The total eclipse of the Sun due to occur in the United States on the afternoon of June 8, 1918, promises to be an interesting event. The shadow cast by the Moon, traveling southeasterly, is due to enter the coast of the state of Washington at latitude +46° 50′ at 2^h 55^m P. M., Pacific Standard Time. It will pass over Heppner and Baker City, Oregon; Hailey and Montpelier, Idaho; Rock Springs, Wyoming; Steamboat Springs, Central City, Golden and Denver, Colorado; Lakin and Ashland, Kansas; Enid, Oklahoma; Jackson, Mississippi; Orlando, Florida; and end at sunset amongst the Bahama Islands.

The astronomical elements for one promising observing site, Baker City, Oregon, are here given:

Latitude	+ 44° 48′
Longitude, W. of Gr	+117° 50′
Pac. St. Time	3 h. 5 m.
Local Mean Time	3 h. 14 m.
Local True Time	3 h. 15 m.
Sun's declination	+22° 50′
Sun's altitude	45°
Duration of totality	1 m. 53 s.

The Chief of the United States Weather Bureau is preparing meteorological and other data of interest to observers of the eclipse, for publication in the near future.

There should be no special difficulty in reaching and finding promising observing stations, and the chances for clear skies in regions between the Cascade Mountains and the Rocky Mountains should be favorable on June 8th.

W. W. CAMPBELL.

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

The Principal Series of Sodium.

The principal series in the spectrum of sodium consisting of the D lines and the ultra-violet lines at wave-lengths 3302, 2853, 2680, 2594, 2544 and 2512 have been known for some time in emission spectra obtained in the laboratory. In 1908, Professor R. W. Wood from a study of the ultra-violet absorption spectrum of sodium was able to extend the members of this series to forty-eight, a greater number than that found even in the case of chromospheric or stellar hydrogen.

A very interesting paper by R. W. Wood and R. Fortrat under the above title in the January, 1916, number of the *Astrophysical Journal* gives the results of a repetition of this work made in the laboratory of Professor Weiss at Zurich. The quartz spectrograph employed by them consists of six 60° and one 30° quartz prisms (the latter backed by mercury), giving by double transmission the equivalent of thirteen prisms. This instrument, the most powerful quartz spectrograph in the world, will resolve, at λ 2414, two lines which differ in wave-length only .03 A and gives a linear dispersion of 1 A to 3.5^{mm}.

The results set forth in the present paper may be briefly summarized as follows: (a) Ten new lines near the head of the series have been added, making the number thus far observed in the principal series of sodium fifty-eight. This in their opinion marks the limit which is at present attainable. (b) Of the original seven members, only the first three had previously been resolved into doublets. In the present investigation they were able to resolve the other four members and to determine the wave-lengths of the components. (c) The wave-lengths of all of the lines of the series have been determined to the third place of decimals, and referred to the secondary standards of Fabry and Buisson. (d) The well-known formula of Ritz for the lines of the principal series of an element represents with a surprising degree of accuracy all of the lines of the series obtained by them. (e) They have photographed all of the absorption lines of the principal series of sodium up to a point within 1.21 A of the calculated head of the series.

The method of studying by means of the absorption spectrum the higher members of a series, not appearing in emission spectra, to which Professor Wood first called attention, is one which will undoubtedly prove of great value in further studies of series relations in spectra.

J. H. MOORE.

NOTE ON STÖRMER'S AURORA OBSERVATIONS.

Professor Störmer of the University of Christiania has published some extremely interesting and important results of his expedition to northern Norway, in the spring of 1913, for the purpose of observing the auroræ. He and an assistant observer occupied two stations, respectively, one at Bossekop and the other at Store Korsnes, separated by a distance of 27.5 kilometers. The two observers were armed with suitable photographic equipment in duplicate, and a telephone line connected them constantly. The auroræ were plentiful and bright, and the observers were able to agree by telephone upon the auroral structure to be photographed simultaneously. By virtue of their different positions with reference to the auroræ, the backgrounds of stars recorded on the simultaneous photographs were differently placed with reference to the auroral structure. Measures of this structure, with reference to the star images on the plates, gave accurate values of the parallaxes of the auroræ, from which their accurate distances from the two observers and from the Earth's surface could be computed.

The results thus far published are for the nights March 3-4, 4-5, and 11-12, 1913. Several hundred measures of auroral altitudes are amongst the results. The very great majority of the auroræ were from 95 to 125 kilometers above the Earth's surface. The preferential altitude was between 95 and 115 kilometers, with a well-defined maximum of preference at almost exactly 100 kilometers. There were no observed altitudes less than 89 kilometers, and only a few greater than 160 kilometers, tho some extended up to 220 kilometers.

The forms and positions of some of the "curtains" of auroral structure were well determined.

Professor Störmer is making a thoro study of the phenomenon of the auroræ on the basis of his observations. He provisionally assigns the origin of auroræ to positively charged electric particles expelled from the Sun and driven into the Earth's higher atmosphere, but he thinks it best to wait until all of the observations have been studied before stating his theory of the auroræ more definitely.

W. W. CAMPBELL.

PTOLEMY'S CATALOG OF STARS.

The Carnegie Institution of Washington has published, with the above title, a revision of the *Almagest* of Ptolemy; or rather that part of the *Almagest* which contains the catalog of 1028 stars, the earliest known list of the measured positions of the brighter stars. The revision was done mainly by Dr. C. H. F. Peters, as a labor of love, but was not completed by him at the time of his death in 1890. Meantime, Mr. E. B. Knobel, formerly president of the Royal Astronomical Society, had undertaken a revision of the manuscripts existing in the famous storehouses of literary antiquities at the British Museum, and at Oxford; and when he discovered that Dr. Peters had been searching the libraries of the European capitals for the purpose of collating the various manuscripts that were in existence, he suggested a combination of their labors, which seems to have been carried out in a most harmonious spirit. After the death of Dr. Peters, Mr. Knobel took charge of all the notes, and encouraged by Prof. Simon Newcomb and various other astronomers, and by public-spirited citizens of this country, the work was put in the form of the publication issued by the Carnegie Institution.

The places of Ptolemy's Catalog are given in celestial latitude and longitude, and the brightness of the stars was recorded on a scale which differs but slightly from the modern photometric scale of magnitudes. No original manuscript is in existence, as far as known, but some twenty-six copies have been consulted in the endeavor to produce a correct list. The latitudes and longitudes were given, nominally, for the epoch A. D. 138, but the computation of the effects of precession shows that the positions are more nearly exact for an epoch about eighty years earlier; and they then correspond with the positions of the stars at the time of Hipparchus, 130 B. C., corrected uniformly by a change of 2° 40′ in longitude, for the effect of precession. In fact it has always been a matter of doubt whether Ptolemy made any actual observations of the places of the stars, since it seems most likely that he simply reproduced the earlier list of Hipparchus, with the corrected longitudes.

The earliest copies that were made were in the Greek, and date from the ninth century. Other copies, in Arabic, are in existence, which appeared to have been derived from original sources. The Latin manuscripts, thus far known, are probably copies of either one of the above. In the copying, performed often evidently by scribes not well informed in the subject, many errors were introduced, due to their ignorance; and besides this difficulty, many errors can be traced to the confusion of the symbols denoting fractions, and even whole numbers. The measures were recorded in fractions of a degree, and it is needless to remark how coarse such measures would appear in comparison with those made by telescopes and modern instruments of precision, where we deal with fractions of a second of arc. For the purpose of recording changes in the sky, the appearance of new stars, or the disappearance of old, the possible movements of the stars, and the transformation of their relative positions due to the precession, the ancient catalog fulfilled a purpose. It is certainly a pleasure to astronomers to see the careful and extensive work done on the revision thus fully recognized by publication.

Dr. Peters came to the old Dudley Observatory at Albany, under Dr. B. A. Gould, and later was for thirty years Director of the observatory at Hamilton College, Clinton, N. Y. His discoveries of asteroids made him famous, in the days when the labor of comparing these faint objects with the sky direct was vastly greater than that involved now in the comparison of photographs of the sky. His charts of faint stars, made in this search, are still in use. And his comet discoveries gave him also some fleeting renown. He was a man of simple manners, a bachelor all his days, genial to his associates but modestly averse to outside intercourse, and his culture outside of scientific lines was also notable. He is credited with the knowledge of Greek, Latin, Hebrew, Arabic, Persian and Turkish, besides the acquaintance with many European languages that was a part of the education of men of the old school.

R. H. TUCKER.

"COMET-SEEKING AND COMET-SEEKERS."

In an article with this title, published in the *Journal of the British Astronomical Association* for December, 1915, Mr. W. F. Denning gives three tables which form an excellent summary of cometary discoveries and discoverers of modern times.

The first table shows "the leading finders of comets during the last 150 years," and includes the names of all who have found five or more comets, counting, however, "only those for which orbits were computed, and in reference to which absolute priority could be claimed." The table contains eighteen names. J. L. Pons (1802-1827) leads with 28 discoveries, but is closely followed by W. R. Brooks (1883-1911) with 25 and E. E. Barnard (1881-1915) with 22. Two other American astronomers are conspicuous on the list, Lewis Swift (1862-1899) with 12 comets, and C. D. Perrine (1895-1899) with 13 comets.

The second table shows the monthly discoveries for the past 123 years (1782-1914), doubtful objects again excluded. July and August appear to be the most favorable months for such discoveries, and it is interesting to note that the latter half of the year is more fruitful than the early half, the numbers being, respectively, 242 and 171.

The third table shows the annual rate of discoveries, grouped in twenty-year intervals from 1782 to 1901, and a thirteen-year interval (1901-1914). The annual average has risen from 1.25 in the first interval to 5.00 in the last. The record year was 1898 with ten discoveries, and 1876 and 1872 were the only barren years.

Mr. Denning comments on the work necessary to find a comet, on its fascination and on its promise of success. His arguments are addressed mainly to English amateurs, but have equal point for amateurs in America.

R. G. AITKEN.

ON THE CALCULATION OF SERIES IN SPECTRA. BY H. G. SAVIDGE AND PROF. J. W. NICHOLSON. PHIL. MAG. **30**, 563, 1915.
NOTE ON THE CALCULATION OF SERIES IN SPECTRA.
BY W. M. HICKS, F. R. S., IBID, **30**, 734, 1915.

These papers have to do with numerical tests to be applied to the wave numbers of lines suspected of being members of a spectral series. To sort out from an apparently heterogeneous group of lines a number which will satisfy relations consistent with formulæ believed to be general in their application to spectral series is, in general, a difficult task, in the absence, at any rate, of distinguishing physical characteristics which may be peculiar to members of such a series. The methods described by the authors of these articles will undoubtedly prove of great assistance to any one attempting to establish series relations in laboratory or celestial spectra.

W. H. WRIGHT.

GENERAL NOTES

James Oliver Mulvey.—James Oliver Mulvey was born in Madison, Indiana, November 5, 1868. He graduated from the Wichita High School and was one of the earlier students of the Lewis Academy of that city.

From early boyhood he showed a strong aptitude for mechanics and chemistry, a bent which he followed thru life. After spending his youth in his own shop at home and then in other active establishments where his naturally inventive genius was sharpened, he became connected with the mechanical department of the Armour Institute in Chicago. Here he acquired, largely by association, a considerable knowledge of physics, particularly optics. He became associated with Albert B. Porter in the Scientific Shop which had attained a substantial footing when Porter's untimely death put an end to the undertaking. Mulvey had charge of the practical side of the business, and it was there I first met him when on my way to Argentina in 1909. Porter spoke in the highest terms of his ability and we discussed to some extent plans for a great reflector for the Córdoba Observatory in regard to which I was then seeking information. Some months after reaching Córdoba I received a letter from Mulvey, telling me of Porter's sudden death and offering his services in connection with our proposed undertaking here. Needless to say it was an unusual opportunity for us, and as soon as plans could be completed (requiring about a year) Mulvey purchased the equipment of machines and supplies for a high-class mechanical shop of medium size and brought them to Córdoba in the latter part of 1910. He installed our shops and at once began the work of improving the efficiency of our instruments.

The first piece of work was typical of our difficulties and of the great need for well-equipped shops. A new measuring-engine for measuring the astrographic plates had been ordered and arrived from Europe at the same time as the shop equipment. In fact, all came to the observatory on the same day. Upon opening the box containing the measuring-engine it was found that the inside case had been *inverted* in the outer, that the repacking at the customhouse had been careless, and in consequence a machine which was *marked* and planned to be carried right-side up always, as the carriage was not protected against inversion, was in nearly its original number of pieces, with handfuls of screws either sheared off or loose in the case. At first sight it looked almost hopeless. But after hurriedly setting up a lathe and drill press, Mulvey in a week's time had the measuring-engine ready for use, the important slides having escaped serious damage—how is still a mystery.

The list of things accomplished by Mulvey is too long to give in any detail. It must suffice to mention only the most important. Improved holding system for the objective of the astrographic telescope to eliminate distortion; improvements in bearings and in the driving system; remounting of both 12-inch equatorial and astrographic telescopes in new domes; regrinding pivots of old meridian-circle which had become much worn; pneumatic holder for curving films for curved-plate camera; and a good equipment of eclipse apparatus. In 1912, preparations were commenced for the work of making the optical parts of the great reflector. These included the construction of an underground optical shop and testing tunnel, three grinding and polishing machines, and the many incidental appliances for testing, etc. All of this work was directly under his charge.

A ruling-engine was also constructed and a Michelson interferometer for testing its screw and end-thrust.

At the time of his death he had concluded the grinding of the 30-inch and was figuring it to a spherical surface for the testing of the 36-inch flat. This latter was ground and polished and the first tests by means of a smaller plane had been made. The rough grinding of the 61-inch disk was in progress.

He designed and constructed the chief apparatus for the observation of total solar eclipses and took part in two expeditions from this observatory—the one to Brazil in October, 1912, and to Russia in 1914, showing great ability for such work.

Perhaps one of his most important contributions was a very efficient system of escapement which he first used in the driving-clocks for the eclipse instruments. This escapement is such that it can be used in any position, the rate can be altered without stopping the clock and all parts are compact and almost completely protected against dust or rain. It is simple, sturdy, stands rough handling well and appears to be as accurate and dependable as any system I have seen. The same system has been adapted to our astrographic telescope, where it has been found to be a great improvement for the arduous work of the chart.

His mind was ever active in seeking greater efficiency; he had the true scientific concentration, knowing no such thing as holidays or definite hours of labor. His inventive faculties were bold and independent, and he had many good ideas covering a wide range of necessities which lack of time alone prevented attacking. He possessed good business ability, but his interest in scientific work was above everything else.

After his return from Russia he had a severe attack of gastric fever and required hospital attendance for about two months. He had recovered from that and also from ptomaine poisoning encountered on a trip into the hills to recuperate, and on the eve of leaving the hospital the second time, March 31st last, was stricken with apoplexy, dying almost instantly.

His services and his example have been of the greatest value to the observatory. The quantity and quality of the work in more than one branch are better owing to his efforts. His work in connection with the great reflector has been of great importance and the excellence of the results which are confidently expected from its use will be due in considerable measure to his efforts. It is, therefore, unfortunate that he could not have lived to reap the credit for his labor, which was the kind which makes for solid improvement without being spectacular.

C. D. Perrine.

Observatorio Nacional Argentino,
Córdoba, December 15, 1915.

Movement for the Abolition of the Fahrenheit Thermometer.— There have been many attempts during the past quarter century to do away with the rather cumbrous system of weights and measures used in England and the United States, and to substitute the decimal system with its manifest advantages. The use of the metric system is now all but universal in the world of science, but, while its theoretical superiority is willingly admitted by the world of commerce and manufactures, it seems evident that the actual change from the foot to the meter as a unit is still a long way in the future in most English-speaking countries, largely because of the enormous capital at present tied up in machines, tools, taps, dies, jigs, templates, and gauges based upon the English inch.

The same objections apply with much less force to the proposition to do away with the Fahrenheit thermometric scale, and the bill at present before the House of Representatives, introduced by Hon. Albert Johnston, is almost unanimously regarded by scientists as a step in the right direction. The provisions of the bill are as follows:—

1. That the centigrade scale of temperature measurement shall be the standard in United States Government publications, the use of the Fahrenheit scale being discontinued at the option of heads of departments or other independent branches of the government, either immediately upon the signing of this bill, or at any time before January 1, 1920, except as provided in Section 3.

2. During the period of transition the Fahrenheit equivalent of centigrade degrees may be added in parentheses or as a footnote or in any other way, if in the opinion of heads of departments or independent officers it seems necessary.

3. The use of the Fahrenheit scale shall be permitted after January 1, 1920, in cases where it is required by State or municipal law, or in certificates of tests of instruments graduated in the Fahrenheit scale.

It is to be hoped that the bill may become a law.

Dr. F. Henroteau, of the Brussels Observatory, has been appointed Visiting Assistant Astronomer in the Observatory of the University of Michigan, on a salary provided by Mr. R. P. Lamont of Chicago. Since the outbreak of the European war Dr. Henroteau has been at the Stonyhurst College Observatory, at Blackburn, England. He is expected in Ann Arbor soon. (*Pop. Astronomy*, March, 1916.)

Total Solar Eclipse of February 3, 1916.—An expedition to observe this eclipse was sent to Tucacas, Venezuela, by the Argentine National Observatory at Córdoba. The expedition was in charge of astronomer Chaudet and was equipped with two cameras for photographing the corona, two prismatic cameras for the flash spectrum and coronal spectrum, a small slit spectrograph and a photometer.

A cablegram received by the Harvard College Observatory on February 9th announces that the Argentine expedition observed the total solar eclipse thru thin clouds. (*Pop. Astronomy,* March, 1916).

The Gold Medal of the Royal Astronomical Society has been awarded to Dr. J. L. E. Dreyer for his contributions to astronomical history and his catalogs of nebulæ.

The Hébert Prize of the Paris Academy of Sciences has been awarded to Professor M. I. Pupin, of Columbia University, for his theoretical and experimental researches in electricity.

Sir F. W. Dyson, English Astronomer Royal, has been elected a corresponding member of the Petrograd Imperial Academy of Sciences.

Dr. Mary M. Hopkins has been appointed associate professor of astronomy at Smith College.

Among the awards granted by the Paris Academy of Sciences in the first distribution of the Loutreuil Foundation are the following: To M. Gonessiat, director of the Algiers Observatory, 3,000 francs for the construction of an apparatus designed to measure the intensity of Hertzian waves and for a vertical seismograph; and to Camille Flammarion, 3,000 francs, for his private observatory at Juvisy.

The Paris Academy has made a grant of 4,000 francs from the Bonaparte Fund to C. Le Morvan, assistant astronomer at the Paris Observatory, for the publication of a systematic and photographic map of the Moon.

Of the prize awards made by the Paris Academy in 1915, those in astronomy are as follows:—

The Lalande Prize was awarded to Lucien D'Azambuja, for his important contribution to the daily measurement of the upper layer of the solar atmosphere and to the recognition of the action exercised by the magnetic field on band spectra; the Valz Prize was awarded to Armand Lambert, for his work as an observer and in applied mathematics; the de Pontecoulant Prize was given to Louis Fabry, for his researches on the asteriods; no award of the Pierre Guzman Prize was made. (*Nature*, January 13, 1916.)

A Terrestrial Crater of the Lunar Type.—Altho the original memoir by Barringer on this subject was read before the United States National Academy some six years ago, many of our readers to whom the original publication may not be accessible will find the brief account of this formation given in *Nature* for January 27, 1916, very interesting reading. Coon Butte, the crater in question, is located in northern Arizona about two and a half miles from Cañon Diablo, famous for its innumerable scattered meteorites, and is a depression about four thousand feet in diameter, with a rim that rises nearly six hundred feet above the floor. A photograph of the crater and a cross-section diagram are given in the article, together with a resumé of the investigations which have been made to explain its origin. For Coon Butte is unique in that it forms perhaps the sole example on the surface of the Earth of a crater of the true lunar type, and is accordingly of great in-

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terest in connection with the various theories that have been advanced as to the origin of the lunar craters, whether by volcanic action or by impact of enormous meteors. All the available evidence seems to indicate that Coon Butte is the result of impact, as there is absolutely no evidence of volcanic activity. The only difficulty in accepting the theory of impact in the case of Coon Butte is the question as to what has become of the vast mass of meteoric matter which caused the crater. Only scattered fragments of nickel-iron have been detected at the depths reached by the borings, and the existence of a vast mass of meteoric iron at greater depths finds no confirmation in the magnetic observations carried on in and around the butte.

It is evident that the striking characters of this singular "crater" are of no less interest to astronomers—so suggestive are the characters in which it agrees with the vast lunar craters—than to geologists, who up to the present have been chiefly attracted by the phenomenon.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD ON MARCH 25, 1916, AT 6:00 P. M., IN THE ROOMS OF THE FACULTY CLUB, BERKELEY, CALIFORNIA.

There were present President S. D. Townley and Directors Leuschner, Cushing, Cornish and Richardson. Dr. Aitken, Chairman of the Publication Committee, and Mr. F. E. Brasch, of the Library Committee, were also present.

The names of Mr. A. O. Tait, of Mountain View, California, and Colonel Thomas L. Casey, of Washington, D. C., were presented for membership and both were duly elected. The Case School of Applied Science, of Cleveland, Ohio, was also made an institutional member.

The Secretary read a communication from Mr. Albert L. Barrows, Secretary of the Pacific Division of the American Association for the Advancement of Science, calling attention to the fact that San Diego had been decided upon for the first meeting of the Pacific Division—time August 9 to 12, 1916,—and asking that the Astronomical Society of the Pacific, as one of the constituent members of the Division, arrange to hold a meeting in San Diego at the same time.

After some discussion as to the practicability of holding a meeting at so distant a point, a motion was made by Director Leuschner to the effect that such a meeting be held by the Astronomical Society at the time and place noted, and that the President be authorized to appoint a Program Committee to act in concert with the Executive Committee of the Pacific Division of the A. S. A. of S. The motion was seconded by Director Cushing and carried, and the President announced that he would appoint the Committee later.

Dr. Aitken, chairman of the committee appointed at the meeting of January 29, 1916, to make certain recommendations concerning the advisability of reducing the dues of the Society, stated that he had associated Director Campbell, of the Lick Observatory, with himself upon the committee and that considerable study had been given to the matter. In view of the fact, however, that further investigation was necessary before specific recommendations could be made, he asked that more time be given his committee for final report. Same was granted.

A verbal report was received from the members of the Library Committee present, respecting the plan recently suggested of depositing the books of the Society in some one of the public libraries of San Francisco, where they would be more accessible to interested readers. The proposition was not received with much favor by the Board, and the Committee was instructed to investigate further and report at the next meeting of the Board.

The Secretary reported the receipt from Paris of the Bruce Gold Medal recently awarded to Dr. George E. Hale of the Solar Observatory, and stated that same had been fowarded to Dr. Hale and his acknowledgment obtained.

Dr. Aitken, of the Publication Committee, reported that he had concluded arrangements with the Sunset Publishing House, of San Francisco, to print future issues of the Society *Publications*.

Adjourned.

D. S. RICHARDSON,
Secretary.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE STUDENTS OBSERVATORY, BERKELEY, CALIFORNIA, ON SATURDAY, MARCH 25, 1916, AT 8:00 P. M.

By courtesy of the authorities of the University of California, this meeting was held in the Students Observatory and the entire scientific program was furnished by Dr. A. O. Leuschner and his talented staff.

The following papers were read before a most appreciative audience:—"Comet *a* 1916" (Neujmin), by Miss Jessica M. Young; "The Riefler Clock," by Professor R. T. Crawford; "On the Universality of the Law of Gravitation," by Professor A. O. Leuschner.

At the close of the addresses President Townley expressed the thanks of the Society.

Adjourned.

D. S. RICHARDSON,
Secretary.

LATER.

The following Program Committee has been appointed by President Townley to arrange for the San Diego meeting in August next, in conjunction with the Pacific Division of the American Society for the Advancement of Science:—

Dr. R. G. Aitken,
Dr. A. O. Leuschner,
Dr. F. H. Seares.

OFFICERS OF THE SOCIETY

S. D. Townley	*President*
C. S. Cushing	*First Vice-President*
H. D. Curtis	*Second Vice-President*
A. H. Markwart	*Third Vice-President*
D. S. Richardson	*Secretary and Treasurer*

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Publication Committee—R. G. Aitken, H. D. Curtis, H. Shapley.
Finance Committee—C. S. Cushing, W. H. Crocker, A. H. Markwart.
Library Committee—D. S. Richardson, F. V. Cornish, F. E. Brasch.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

	4 pp.	8 pp.	12 pp.	16 pp.
50 copies, without covers	$2.00	$4.00	$5.50	$7.00
50 copies, with covers	4.00	6.00	7.50	9.00

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. XXVIII. San Francisco, California, June, 1916 No. 164

ASTRONOMICAL OBSERVATIONS IN 1915.

Made by TORVALD KÖHL, at Odder, Denmark.

VARIABLE STARS.

(The instrument used is a 3-inch Steinheil, power 42.)

S *Ursæ Majoris*.[1]

Jan.	10:	S 2 steps > f′
Feb.	3:	< g.
Feb.	8:	id.
Mar.	22:	= g.
	23:	id.
	31:	1 step > f′.
Apr.	4:	3 steps < e.
	11:	id.
Aug.	22:	= f.
	31:	id.
Sept.	2:	1 step > g.
	5:	= g.
	7:	id.
	9:	id.
Sept.	11:	= g.
	12:	id.
	14:	id.
	18:	id.
	28:	invisible
Oct.	3:	id.
	7:	< g.
	26:	= g.
Nov.	11:	in the middle between e and f′
	23:	3 steps < e.
	25:	id.
Dec.	4:	2 steps < e.
	9:	1 step < e.

T *Ursæ Majoris*.[2]

Jan:	10:	T 5 steps > a.
Feb.	3:	in the middle between a and b.
Mar.	22:	= f.
	23:	id:
	31:	3 steps < g.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 73, **12**, 56.
[2] Vide the sketch in the *Publications A. S. P.*, No. 22, **4**, 63.

Feb. 8: = c.
Apr. 4: 4 steps < g.
11: very faint.
Aug. 22: 3 steps > a.
31: id.
Sept. 2: id.
5: 2 steps > a.
7: id.
9: id.
11: id.
12: id.
Sept. 14: 1 step > a.
18: = a.
28: ½ step > a.
Oct. 3: id.
7: = a.
26: = b.
Nov. 14: = c.
23: 2 steps > d.
25: id.
Dec. 9: in the middle between e and g.

W *Pegasi*.[1]

Jan. 10: W invisible.
Sept. 2: in the middle between d and e.
5: 2 steps > e.
7: 1-2 steps > e.
Sept. 11: 1 step > e.
14: = f.
Oct. 7: 2 steps < g.
Nov. 25: utmost faint.

SS *Cygni*.[1]

Jan. 10, 6^h: SS 3 steps > e.
Feb. 3, 7^h: < g.
Apr. 11, 12^h: invisible.
Aug. 31, 9^h: 2 steps < c.
Sept. 2, 9^h: id.
Sept. 5, 9^h: in the middle, betw. d and e.
Sept. 7, 9^h: < e. > f.
11, 9^h: 1 step < f.
Nov. 14, 10^h: = g.
Dec. 9, 8^h: < h.

U *Herculis*.[1]

Apr. 11: U in the middle between a and b, b 2 steps > c.
18: 1 step < a.
28: id.
Sept. 2: = g.
5: id.
7: id.
Sept. 11: 1 step < g.
14: = h.
28: id.
Oct. 3: 2 steps < h.
7: 3 steps < h.
29: utmost faint.
Nov. 25: invisible.

S *Persei*.[2]

Apr. 11: S = e.
18: = e.
Aug. 31: 1 step < d.
Sept. 5: = d.
Sept. 14: in the middle, between d and e.
Oct. 26: < d. > e.
Nov. 15: = e.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 141, **24**, 109.
[1] Vide the sketch in the *Publications A. S. P.*, No. 135, **23**, 42.
[2] Vide the sketch in the *Publications A. S. P.*, No. 135, **23**, 43.

Var. 25, 1913, *Ursæ Majoris*.

(B. D. + 60° 1412 ($9^m.5$) = f in the sketch on T *Ursæ Majoris*)

Jan.	10:	f 2 steps < g.
Feb.	3:	= g.
Mar.	22:	2 steps > g.
	23:	> g
	31:	a little > g.
Apr.	4:	1 step > g.
	11:	id.
Aug.	31:	1 step < g.
Sept.	2:	id.
	5:	½ step > g.
	7:	= g.
	11:	id.
Sept.	12:	1 step > g.
	14:	= g.
	18:	1 step < g.
	28:	½ step > g.
Oct.	3:	1 step < g.
	7:	1 step > g.
	26:	id.
Nov.	14:	= g.
	23:	> g.
	25:	1 step > g.
Dec.	9:	1 step < g.

Several other stars have been watched, such as Y *Tauri*, which in this year have been noted > A = B. D. + 20° 1095, especially in March and April.

LARGE METEORS.

Fireballs have been observed from stations in Denmark and surrounding countries on the following dates: January 10th, 17th (five observations), 23rd, February 8th, 26th (two observations), 27th, March 22nd, 25th, 28th, April 16th, May 9th, 11th, 13th (seventeen observations), 24th (six observations), June 11th (two observations), 21st, 23rd, 25th (two observations), 30th, July 2nd, August 11th, September 7th, 9th, 16th (two observations), 19th (seven observations), October 8th (three observations), November 16th (two observations), December 12th, 16th, 20th, 30th.

SHOOTING-STARS.

Shooting-stars were observed at five stations in Denmark, one in Schleswig and one in Sweden from August 9th to 12th, furthermore at two stations in Denmark in the morning-hours on November 15th and 16th. At these stations 279 paths of shooting-stars were mapped, and 10 proved suitable for calculation. These 10 meteors have given the following results:—

FROM OBSERVATION.

No.	Time, P. M.	Station.	Beginning.	Ending.	Mag.	Observer.
1	Aug. 11, 10ʰ 30ᵐ	Tyderup	285°+46°	....	2	M. Povlsen.
		Copenhagen	233 +25	....	2	S. Kierulff.
2	Aug. 11, 10 42	Ulderup	....	296°+11°	3	A. Bartram.
		Copenhagen	....	239 ÷ 9	3	S. Kierulff.
3	Aug. 12, 10 1	Varde	25 +48	11 +47.5	2	N. Bossen.
		Barsebäk	190 +55.5	204 +35	2	W. Norlind.
4	Aug. 12, 10 40	Varde	19 +40	8 +42	5	N. Bossen.
		Arlöse	190 +62	200.5 +36	2	K. Kaestel.
5	Aug. 12, 10 42	Ulderup	....	49 +30.5	3	A. Bartram.
		Barsebäk	....	222 +24		W. Norlind.
6	Aug. 12, 11 18	Odder	339 + 0	357 ÷ 6	1	J. Skakke.
		Tyderup	310 +10	331 + 4	1	M. Povlsen.
7	Aug. 12, 11 27	Varde	57 +47	....	3	N. Bossen.
		Tyderup	148 +72	....	1	M. Povlsen.
8	Aug. 12, 12 4	Varde	....	26 +13	4	N. Bossen.
		Tyderup	....	330 +30	1–2	M. Povlsen.
9	Nov. 15, 16 32	Husby	182 +33	201 +44	2	Rasmussen.
		Tyderup	30 +62	0 +55.5	2	M. Povlsen.
10	Nov. 15, 16 42	Husby	....	212 +29	2	Rasmussen.
		Tyderup	....	316 +64	2	M. Povlsen.

FROM CALCULATION.

No.	Beginning.			Ending.			Real length of the path.	Radiant.	
	h	λ	φ	h	λ	φ	β	AR	Decl.
1	55.0	1° 14′.4	55° 35′.7						
2				38.5	2° 52′.8	54° 39′.2			
3	134.4	1 32 .4	56 43 .0	107.3	2 16 .8	56 11 .3	80.7	53	+44°
4	96.7	2 4 .6	56 4 .3	67.0	2 58 .8	55 48 .6	70.4	33	÷35
5				37.4	0 53 .5	55 47 .3			
6	75.6	1 3 .2	54 59 .0	37.6	0 44 .2	55 15 .7	53.5	257	÷16
7	120.9	1 28 .7	56 59 .4						
8				84.6	0 54 .5	55 19 .3			
9	111.7	2 17 .6	50 19 .0	97.0	2 34 .1	56 44 .5	53.6	136	÷14
10				37.7	1 25 .7	56 35 .8			

ʰ and β are expressed in kilometers; λ is west longitude from Copenhagen; φ is north latitude; ʰ is the altitude of the meteor above the Earth's surface.

The Carina-Meteor catalog has now reached the number of 6266 meteors, observed from stations in Denmark and surrounding countries from 1875 to 1915 inclusive.

From August 2nd to 7th, inclusive, astronomical lectures were held at the Carina Observatory in Odder.

In the estimation of variable stars I have been assisted by Mr. J. Skakke, who, also by the aid of a 78^{mm} Darlot lens, has photographed several regions of the heavens.

THE RELATION OF THE SYSTEM OF STARS TO THE SPIRAL NEBULÆ.

By G. F. Paddock.

Endeavors have recently been made to present a comparative list[1] of average radial or line-of-sight velocities of the several different kinds of objects in the sky, and to discuss the relation of the spiral nebulæ to the other objects. The list is arranged in the order: diffused nebulosities, stars from early to late type, nebulæ of regular forms, and spiral objects. The average radial velocities of all except the spirals range in increasing magnitude from zero to fifty kilometers per second. But a considerable jump is noticed from the fifty kilometers to 400 kilometers for the average of the spirals.

This suggests the question: Are the spirals dissociated from the star system? Bearing on this problem is the matter of the derivation from observed velocities of a value for the motion thru space of our Sun, for which the star system gives a velocity of 20 kilometers per second and an apex in the vicinity of 270° Right Ascension and +30° Declination. The question has accordingly led to a discussion of the velocities of spirals, first by Truman[2] and then by Young and Harper[3], for the purpose of finding a possible space motion of our system of stars, including the Sun, relative to a possible system of spirals of which our stellar system may be a unit and the spirals each perhaps a system of stars.

There are available for investigation in the case of the spiral nebulæ the radial velocities of 15 spirals observed recently by Slipher, who brings out the following points:[4]

1. The spirals show, in confirmation of earlier observations, dark line spectra, some of them almost pure G and K classes, which differentiates them from the gaseous nebulæ and the dense star clusters.

2. The average velocity is positive between 300 and 400 kilometers.

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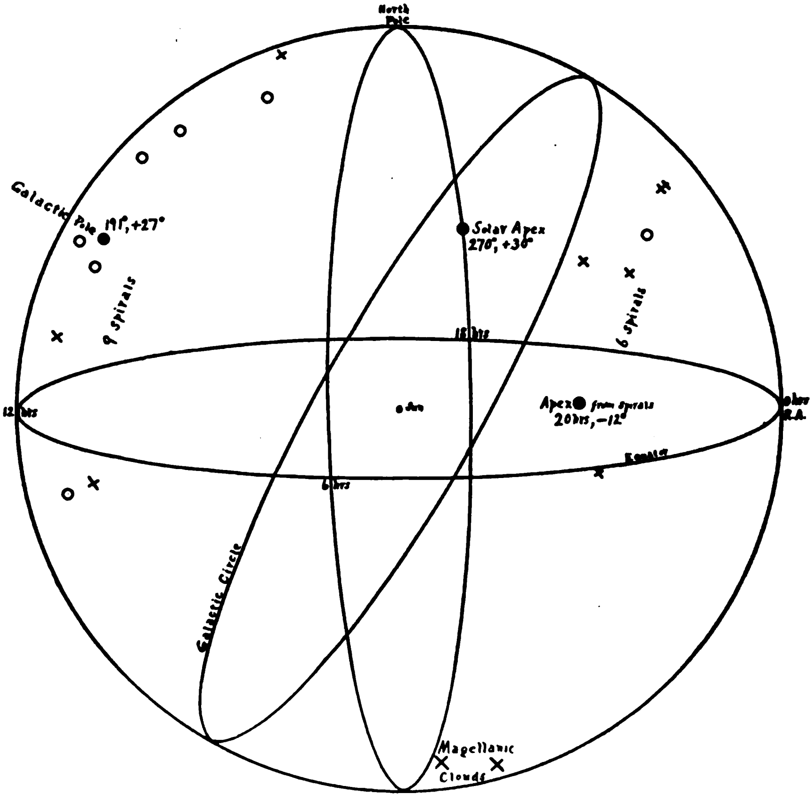
[1] *Pop. Astr.*, **24**, 109, Feb., 1916.
[2] *Pop. Astr.*, **24**, 111, Feb., 1916.
[3] *Jour. R. A. S. Can.*, **10**, 134, March, 1916.
[4] *Pop. Astr.*, **23**, 36, Jan., 1915.



Approximate Positions of the Observed Spiral Nebulæ of the Magellanic Clouds, and of the Derived Apex.

(Crosses indicate positions in the front hemisphere and circles those in the rear hemisphere.)

3. Nine observed spirals north of the Galaxy all have positive velocities averaging 400 kilometers, and six observed south of it have three positive and three negative, averaging less than 200 kilometers positive.

4. Four of the spirals which are of spindle shape, suggesting edgewise view, have the higher velocities, suggesting the idea of principally edgewise motion for spirals.

5. The 25-fold difference in the average velocities of stars and of spirals does not readily admit the inclusion of the spirals in the idea of an evolutional increase of velocity with advance of spectral type which is construed from the sequence of star velocities.

To Slipher's data have been added by Young and Harper the velocities observed by Wilson[5] for the gaseous planetary nebulæ found in the Magellanic Clouds whose high values probably indicate non-association with our system of stars.

TABLE OF VELOCITIES OF SPIRAL NEBULAE AND OF GASEOUS NEBULAE IN THE MAGELLANIC CLOUDS

OBJECT		R. A.		Decl.		Observed by Slipher km. per sec.	VALUES USED BY			
N. G. C.		h	m	°	′		Truman km. per sec.		Young and Harper km per sec.	
7331[1]	South of Galaxy	22	32	+33	54	+ 300±	+ 300	+200	+ 300	+87
221		0	37	+40	19	− 300	− 300		− 300	
224		0	37	+40	43	− 300	− 300		− 330[6]	
598		1	28	+30	9	− . . .	.. . . .		− 278[7]	
1023		2	34	+38	38	+ 200±	+ 200		+ 200	
1068		2	38	− 0	26	+1100	+1100		+ 931[8]	
3031	North of Galaxy	9	47	+69	32	+ small	+ 100	+440	0	+410
3115		10	0	− 7	14	+ 400±	+ 400		+ 400	
3627		11	15	+13	32	+ 500	+ 500		+ 500	
4565		12	31	+26	32	+1000	+1000		+1000	
4594		12	35	−11	3	+1100	+1100		+1000	
4736		12	46	+41	40	+ 200±	+ 200		+ 200	
4826		12	51	+22	13	+ small	+ 100		0	
5194		13	25	+47	42	± small	0		0	
5866		15	4	+56	9	+ 600	+ 600		+ 600	
Average.		. . . . . .		. . . .		+ 340+	+ 360		+ 280	
						Wilson				
1644	L. Mag. Cl.	1	6	−73	44	+ 158			+251[9]	
1714	G. Mag. Cl.	5	20	−68	47	+301	+275			
1743						+254				
2070						+276				
2111						+268				

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[5] *Proc. Nat. Acad. Sci.*, **1**, 183, March, 1915.

[6] For the *Andromeda* Nebula Pease and Adams found —329km: *Publ. A. S. P.*, **27**, 134, June, 1915; and Wright found —304 km: *idem.*

[7] F. G. Pease, *Publ. A. S. P.*, **27**, 239, Dec., 1915: Three bright lines 5007A, Hβ, Hγ, from the brightest condensation in the nebula about 10′ *n f* the nucleus, give the radial velocity —278km; *idem* **28**, 34, Feb., 1916: the spectrum of the nucleus is about F_0 Class and gives a radial velocity of the order of —70km.

[8] Mean of Slipher's + 1100km and Pease's + 765km, *Publ. A. S. P.*, **27**, 133, June, 1915. An observation at Mount Hamilton gives + 910 km: J. H. Moore, *Publ. A. S. P.*, **27**, 192, 1915.

[9] This value, + 251km., used by Young and Harper, is the simple mean of the five velocities given.

The data as given by Slipher and the values adopted by Truman and by Young and Harper are presented in the accompanying table. Similar values have been found for the velocities of the *Andromeda* nebula and its companion, N. G. C. 224 and 221 respectively, and they have been taken as a single value. Truman has assumed +100^{km} for the "small positive" values given by Slipher, while Young and Harper have used zero. The latter have the advantage of one extra value and revised values in two or three cases. Their average velocity, algebraic, is accordingly less. It is of course likely that this average will diminish with increasing numbers of observed velocities. The component of solar motion has not, so far as is known, been applied to the above velocities; but being not greater than 20^{km} for any case, and hence very small in comparison with the magnitude of these velocities, it will have small effect on results. It is to be noted that the velocities of three of the nebulæ in the list have been substantially confirmed.

The results of solution[10] of the above data for a space motion and direction of the system of stars relative to the spirals (and the Magellanic Clouds in one case) as a group, are as follows, negative velocity meaning motion toward the apex:

	VELOCITY.	APEX.	OBJECTS.
Truman	-670^{km}	20^{hrs} R.A., $-20°$ Decl.	14 spirals.
Young and Harper	$-598^{km} \pm 234$	$20^{h}\ 24^{m}$, $-12°\ 10'$	15 spirals and the two Magellanic Clouds.

Young and Harper remark that if the size of a probable error relative to the magnitude of a result indicates inversely the reliability of the result, the chances are favorable that the above derived velocity has a significance. Nevertheless, their derived probable error, ± 234^{km}, and those here given below, are very large.

In order to discuss these results, certain points with regard to the data must be considered. On the accompanying diagram of the celestial sphere are located the Celestial Equator and North Pole, the Pole of the Galaxy and the Galactic Circle, the apex of the Sun's motion with respect to the stellar system, and the newly derived apex of the supposed motion of the system of stars with respect to the observed spirals. Besides these elements, the positions of the observed spirals and of the Magellanic Clouds are approximately indicated by crosses if on the front hemisphere and by circles if on the rear hemisphere. The circles around the points indicating the Galactic Pole and the Apices signify that these points lie on the rear hemisphere. Perspective causes the Magellanic Clouds to appear nearer the celestial South Pole than they actually are in the sky.

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[10] Campbell, *Stellar Motions*, page 170, etc.

The spirals observed are thus seen to be divided into two almost oppositely placed groups, each contained in less than an octant of the sphere. Six south of the Galaxy are found in the region of zero hours of right ascension, within four hours of right ascension and forty degrees of declination of one another, while nine north of the Galaxy are in the region of twelve hours of right ascension and within five hours of right ascension and eighty degrees of declination of each other. The well-known distribution of the spirals toward the Galactic Poles is of course only partially evident here, the south polar regions not being observable. These two groups of spirals and the Magellanic Clouds are distinctly separated with respect to angular distance on the celestial sphere and seem to form a well-arranged system of three points with respect to which to determine the motion of the observer and the stellar system. These objects, however, can hardly be considered to form a unitary system of associated objects, for it must be noticed that the average velocity of each of the three groups of objects is decisively positive, which means that they are receding not only from the observer or star system but from one another. Accordingly a solution for the motion of the observer thru space should doubtless contain a constant term to represent the expanding or systematic component whether there be actual expansion or a term in the spectroscopic line displacements not due to velocities. This brings up the question whether these large displacements are to be interpreted as due entirely to velocities. Certainly in one case it is doubtful, for on Lick Observatory plates of N. G. C. 1068 the bright lines are broad and fuzzy, indicative of bands, perhaps something like Wolf-Rayet bright bands.

The required constant term would correspond to the term *K* which has been introduced into solutions for solar motion. Altho in the latter instance, it has turned out to be only a few kilometers in amount, it seems likely to be of considerable magnitude in the case of the present list of objects, and it is probable that its inclusion in the solution for space motion of the observer would affect the derived velocity. Assuming an apex, it is easy to test the matter by the solution of the equation

$$V_0 \cos D + K = V$$

in which *K* is the constant term, *V* the observed velocity, V_0 the Sun's space motion away, if positive, from the apex, and *D* the apical distance determined by the equation

$$\cos D = \cos \delta_0 \cos \delta \cos (\alpha_0 - \alpha) + \sin \delta_0 \sin \delta$$

where α_0 and δ_0 are the right ascension and declination of the assumed apex.

The results of such a test are as follows:

APEX.	K	V_0	r
For Young and Harper's Apex, $20^h\ 24^m$, $-12°\ 10'$	$+ 248^{km} \pm 88$	$- 295^{km} \pm 202$	$\pm 285^{km}$
Idem, omitting *K* for nebulæ in the Mag. Cl.	$+ 255^{km} \pm 92$	$- 267^{km} \pm 199$	$\pm 282^{km}$
For the Solar Apex, 270°, + 30°	$+ 338^{km} \pm 78$	$- 162^{km} \pm 175$	$\pm 291^{km}$
[11] For an apex at the Galactic Pole, 191°, + 27°	$+ 295^{km} \pm 86$	$+ 81^{km} \pm 110$	$\pm 284^{km}$

The velocities as used by Young and Harper have been used here, except that in the second case the value for the one nebula in the Lesser Magellanic Cloud and the mean of the four in the Greater Magellanic Cloud have been used separately and without *K*, that is, the coefficient of *K* has been taken as zero in their respective equations of condition, for the reason that these objects are gaseous planetary nebulæ observed with higher dispersion than was used for the spirals, and that the plates show narrow bright lines whose displacements are quite certainly to be ascribed to velocity. The resulting values of K and V_0 are not, however, very different from those in the first case.

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[11] The component of $V_0 = -267$km in the direction of the South Galactic Pole is +252km. The value +81km in the last case probably has no significance, but the persistence of a large value for *K*, wherever the apex, is to be noted.

Least square solutions of the 15 or 16 equations of condition were made for each group of results. The probable error of a single observation is given in the last column (r) and is seen to be very large and of the same order of magnitude as the derived values for K and V_0. The probable error of V_0 is nearly as large as V_0 and throws great uncertainty on the magnitude of the space motion derivable from the present data. Again, the probable error of K is one-third the size of K and may or may not indicate a degree of significance for K. It may be concluded, however, that values of similar magnitude for both K and V_0 exist with a similar degree of certainty in the present limited amount of data. The presence of so large a value for the apparent systematic quantity K may probably be accounted for otherwise than as mentioned above. It has already been remarked that the algebraic average of the velocities of spirals will probably diminish with increasing numbers of observed velocities. Probably, likewise, the value of the apparent systematic term will diminish, so that it may therefore be concluded that its appearance here is the result of insufficient data. It is to be noticed, in particular, that no velocities of spirals are at hand for the regions of the derived apex or antapex, which circumstance tends to introduce indeterminateness into a solution for motion of the observer with reference to the group of objects observed.

May, 1916.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1916

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter.	July 8th, 3^h 55^m A.M.	First Quarter.	Aug. 6th, 1^h 6^m P.M.
Full Moon...	" 14th, 8 40 P.M.	Full Moon...	" 13th, 4 0 A.M.
Last Quarter..	" 21st, 3 33 P.M.	Last Quarter.	" 20th, 4 53 A.M.
New Moon...	" 29th, 6 15 P.M.	New Moon...	" 28th, 9 25 A.M.

The third eclipse of the year, a Partial Eclipse of the Moon, will occur on the evening of July 14th, and will be visible generally thruout the United States. The maximum obscuration of the Moon will be four-fifths of its diameter, so this eclipse will be much more notable than that which occurred in January. The circumstances of the eclipse are as follows:

Moon enters penumbra	July 14th, 6^h 18^m P. M.
Moon enters shadow	7 19 P. M.
Middle of eclipse	8 46 P. M.
Moon leaves shadow	10 12 P. M.
Moon leaves penumbra	11 14 P. M.

The fourth eclipse of the year is an *Annular Eclipse of the Sun*. It will not be visible even as a partial eclipse except in the regions of the Indian and South Pacific oceans. The line of central eclipse runs thru Australia and Tasmania.

On the night of July 23-24th the Moon will again pass over the *Pleiades* group and a number of the brighter stars will be occulted. As the Moon is in her last quarter the immersions will occur at the bright limb.

The Earth reaches its maximum distance from the Sun on the night of July 2nd.

Mercury is a morning star at the beginning of July, rising a little more than an hour before sunrise, having reached greatest west elongation at the end of June. By the middle of the month the interval is less than one hour and the planet is too near the Sun for naked eye view. It passes superior conjunction and becomes an evening star on the morning of July 28th. By the end of August it will have nearly reached greatest east elongation. The elongation will be rather a large one, but the planet is so far south of the Sun, about 11°, that it remains above the horizon less than an hour after sunset, too near for a naked eye view. *Mercury* is in conjunction with *Venus* on July 13th and with *Saturn* on July 21st, but the planets are all too near the Sun for easy view.

Venus passes inferior conjunction with the Sun on July 3rd and becomes a morning star. Its great brightness will allow it to be seen a few days later in the early morning twilight. The two bodies separate quite rapidly and shortly after the middle of the month *Venus* will rise an hour before sunrise. It will then be an easy object. By the end of August it will rise more than three hours before sunrise. By the end of August the planet will have nearly reached greatest west elongation. Half way between conjunction and greatest elongation *Venus*, on August 9th, will again be at its greatest brilliancy, being visible to the naked eye for some weeks in full daylight. Its motion among the stars is about 10° westward up to July 25th. It then begins to move eastward along a line south of the line of its westward motion, and by the end of August will have moved 21° eastward to a point about 14° south of *Castor* and *Pollux*.

Mars is still in the evening sky, setting shortly before 11 P. M. on July 1st, about three and one-half hours after sunset. The Sun is slowly overtaking it in their common eastward motion among the stars, so that by the end of August it sets less than two hours after the sun, but it is still far enough away to be easily visible in the evening twilight. During the two-months' period it moves about 34° eastward and 15° southward from the eastern part of *Leo* to the corresponding part of *Virgo*. Toward the end of August it is near the first magnitude star *Spica*, *α Virginis*, passing about 2° north of the star on August 27th. Its actual distance from the Earth is continually increasing altho at a smaller rate, and there is consequently a diminution in brightness of about one-third, but it still remains a little brighter than the pole star.

Jupiter rises shortly after midnight on July 1st and shortly before 9 P. M. at the end of August. It is in the western part of the constellation *Aries* and moves about 4° eastward and 1° northward up to August 25th, and then begins to move slowly westward. This retrograde motion will continue about four months, until near the end of December, and will amount in all to about 10°.

Saturn is an evening star on July 1st, but too close to the Sun for naked eye view. The Sun rapidly overtakes it in their common eastward motion, and conjunction is passed on July 12th. The two bodies separate rapidly and by the end of the month the planet rises an hour and twenty minutes before sunrise. For the last week of July it can be seen in the morning twilight if the weather conditions are good. The distance between Sun and planet continues to increase so that at the end of August the planet rises at about 2 A. M. It is in the constellation *Gemini* and moves about 8° eastward during the two months on a line about 10° south of *Castor* and *Pollux*. *Saturn* will be occulted by the Moon on the night of August 24-25th. The occultation will be visible in general thruout the United States at 3^h to 4^h A. M. in the eastern part of the country, and earlier by local time in the west.

Uranus will rise shortly before 10 P. M. on July 1st and long before sunset on August 31st; so it is getting into fair position for observation. It passes opposition on August 10th. It remains in the constellation *Capricorn* and moves about 2° westward during the month. No bright stars are very near, but at the end of August it is about 6° west of the third magnitude δ *Capricorni*, 4° west of the 4th magnitude γ *Capricorni*, and about 1° north of the small fourth magnitude ι *Capricorni*.

Neptune reaches conjunction with the Sun on July 25th, and thruout the two months is too near the Sun for observation even with a telescope.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Note on the Relative Velocities Observed Within Some of the Planetary Nebulæ.

Since our announcement of the discovery of spectroscopic evidence of the rotation of the planetary nebula N. G. C. 7009 (R. A. = $20^h\ 58^m$), we have extended the observations to a number of well-known planetaries. We have obtained spectrograms, with high dispersion for this line of investigation, of the following objects:

N. G. C. 418	= 5^h	$22^m.9$	= —12°	46′
N. G. C. 2392	7	23 .3	+21	7
N. G. C.$_2$ 3568	12	30 .4	+83	7
N. G. C. 6210	16	40 .3	+23	59
N. G. C. 6543	17	58 .6	+66	38
N. G. C. 6572	18	7 .2	+ 6	50
N. G. C. 7009	20	58 .7	—11	46
N. G. C. 7027	21	3 .3	+41	50

Our spectrograms of N. G. C. 418 and N. G. C.$_2$ 3568 show no inclination of the nebular lines, while those of all the other objects give marked evidence of relative motion within them. With the exception of N. G. C. 2392 the results for the relative motions within each nebula appear to be capable of interpretation on the hypothesis that the nebula is rotating, altho there are indications, at least for the outer portions of some of these objects that the phenomenon may be more complicated than that due to simple rotation.

Two spectrograms of N. G. C. 2392 obtained with the slit passing centrally across the nebular image in position angles respectively 5° and 95° show lines of a remarkable form. The shape of the lines is similar in the two spectrograms, and their central and brighter section, corresponding to the central portion of the nebula, some 11 or 12 seconds of arc in diameter, is roughly that of a drawn bow concave toward the violet. Measures of these lines indicate a relative velocity of some 80 km./sec. for points at the ends with reference to the middle point of the bow. We do not undertake now to interpret the remarkable line form observed, but shall hope to do so later.

W. W. Campbell.
J. H. Moore.

May, 1916.

On the Rotation of the Planetary Nebula N. G. C. 6572.

We have recently secured a number of observations of the well-known planetary nebula Struve 6, or N. G. C. 6572, with spectrographs of high dispersion, in order to test it for possible evidence of rotation. This nebula, one of the brightest of its class, is oval in form with a bright nucleus near the center. The brighter portions, as recorded on photographs of short exposure with the Crossley reflector, have diameters of 9 and 14 seconds of arc along the minor and major axes, respectively, while on long exposure photographs these diameters are about 13 and 16 seconds of arc. The major axis is in position angle 0°, or north and south.

Beginning with November 30, 1915, we have secured a series of spectrograms with two three-prism spectrographs having cameras of focal lengths, respectively, 16 and 32 inches. These spectrograms, taken with the slit of the spectrograph in position angles 0°, 45°, 135°, and 180°, give nebular lines whose form is approximately that of a very shallow letter S.

Our preliminary results indicate that the central portion of the nebula N. G. C. 6572, some 3 seconds of arc in diameter, is rotating about an axis in position angle approximately 90°. The relative velocity of the points at the extremities of this diameter is of the order of 5 or 6 kilometers per second. The direction of rotation of the central portion is in the sense that a point on the major axis north of the center is receding, while a point south of the center is approaching us. The inclination of the outer ends of the lines corresponding to portions of the nebula 2 to 5 seconds of arc from the nucleus are such as to indicate a rapid decrease in the speed of rotation as we go out from the central mass. This phenomenon, to which we have previously referred in the case of N. G. C. 7009, we interpret to mean that the outer strata of the nebula lag behind.

A spectrogram taken with the slit in position angle 90° (east and west), that is, along the minor axis, shows no appreciable inclination or curvature of the nebular lines. We, therefore, do not confirm Hartmann's[1] observation of a difference of velocity of the order of 6 kilometers per second between the west edge and center of the nebula.

W. W. Campbell.
J. H. Moore.

May, 1916.

The Orbit of β 80.

The binary system β 80 (R. A. = 23^h 13^m 46^s; Decl. = + 4° 52′; Mags. = 8.3—9.3) was discovered by Burnham in 1875 with his six-inch refractor. The system soon gave promise of being of more than usual interest because in addition to a large proper motion (0.″48 towards 105°) the measures showed rapid orbital motion.

At the time of discovery the angular separation between the components exceeded 1″.0, but it rapidly diminished until it fell to a minimum of 0″.15 in 1904-05. Since then it has increased, and is now about 0″.7. The angular motion since discovery forty years ago has exceeded 300° and the star has been well observed.

Nevertheless it is not possible even now to compute an orbit which may be regarded as reliable, because it is quite uncertain what the maximum apparent separation of the two components will be. See published an orbit (period 63.5 years) in 1906 which satisfied the observations to that date, but in the past ten years the observed and computed paths have diverged, and the residual in angle (O-C) now exceeds 21°.

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[1] *Ap. Journ.*, **15**, 287, 1902.

I have recently made a new investigation of the data and have found that orbits with periods of 95 years and of 156 years will satisfy the observed position angles with equal accuracy. The shorter period, however, gives a rather better representation of the observed distances. It is also in favor of the shorter period that Struve failed to detect the pair. For 1831, the shorter period orbit gives a computed angular separation of only 0″.8, while the larger orbit gives 1″.75. Measures for another ten or twenty years are needed before a really satisfactory orbit can be computed. The two sets of elements which I have derived are as follows:

ELEMENTS.

	I	II
P	95.2 years	156.0 years
T	1905.0	1904.90
e	0.77	0.84
a	0″.72	0″.955
i	±22°.95	0°.0
ω	98.0	
Ω	6.2	102.3 (position angle of periastron)

According to Kapteyn and Weersma, the absolute parallax of the system is +0″.021. Assuming the correctness of this value and of elements I, the mass is 4.45 times the Sun's mass, the semi-major axis of the orbit 34 astronomical units, and the absolute magnitudes of the two components 4.9 and 5.9 respectively.

R. G. AITKEN.

May, 1916.

NOTE ON THE NEBULA N. G. C. 6610.

In comparing photographs of Selected Area No. 86 made for the determination of standard magnitudes it was noted that an object, apparently a planetary nebula, shown on a plate of an hour's exposure on August 27, 1911, does not appear on any of the other plates. The N. G. C. gives no record of any nebula in the position of the suspected planetary. The catalog declination of N. G. C. 6610 is, however, the same as that of the object, but the recorded right ascension is 11^s greater. On the other hand, none of the photographs shows any nebula in the catalog position of N. G. C. 6610 as bright as the 17th or 18th photographic magnitude. Either the N. G. C. position is in error or the nebula is variable. A mistake of 10^{s} in right ascension would probably identify N. G. C. 6610 with the object on the Mount Wilson plate, but in this case we should certainly have a case of variability. The object photographed here shows the graded intensity and the granular or mottled structure which is characteristic of many small nebulæ and fits the N. G. C. description of No. 6610 well enough, but it would be rash to say that it is not a photographic defect. Its position for 1875 is

$$18^{h}\ 11^{m}\ 26^{s} \quad + \quad 14^{\circ}\ 57'.2$$

In the meantime, it is clear enough that N. G. C. 6610 is subject to the uncertainty mentioned above.

Frederick H. Seares.

Color-Photographs of Nebulæ.

Color-sensitive plates and special ray-filters have been used on one or two occasions to test the homogeneity of radiation from different parts of a nebula. Keeler, for example, compared ordinary photographs of the *Orion* nebula with others on isochromatic plates exposed behind a yellow screen, and was thus able to confirm Campbell's visual observations of variations in the relative intensity of the spectrum lines. In 1905, Hartmann, with filters of more restricted transmissibility, showed that the great photographic activity noted by Keeler in certain regions was to be attributed to the unusual intensity of the line λ3727. Again a red-sensitive plate and a filter transmitting nothing to the violet of λ5700 enabled Mr. Hale to demonstrate the reality of the reddish fringe observed by Barnard, and later by Keeler, along the southern boundary of the Huyghenian Region, and to show that it was probably due to a local intensification of the Hα line of hydrogen.

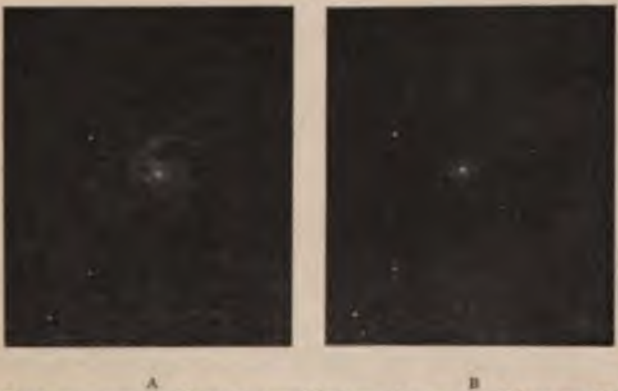
It seems not unlikely that the principle involved in these experiments can be made the basis of an analytical method of considerable usefulness. Photographs thus obtained show admirably, but without differentiation, the distribution of whatever luminosity lies within the limiting wave-lengths defined by the color sensibility of the plate and the transmissibility of the filter. By proper adjustment of plate and filter the photographs can be made nearly monochromatic, and we approach the method of spectrum analysis, but with the added advantage of a record of the distribution of luminosity. But if we approach monochromatic radiation too closely we encounter the difficulty which so generally limits observation with the spectrograph—the exposures become excessively long if not impossible. On the other hand, a step in the opposite direction means a sacrifice in the refinement of analysis. Experience only can determine the nature of the compromise which must here be effected.

In the meantime, preliminary experiments with ordinary and isochromatic plates, the latter used with a yellow filter transmitting to the red of λ4900, have given some interesting results which are briefly described below. All of the photographs have been made with the 60-inch reflector. The exposures for the isochromatic plates were from four to six times those for the ordinary plates, this ratio giving comparable images for the bluest stars. For brevity the two kinds of plates will be referred to as "yellow" and "violet," respectively.

Altho the yellow filter begins to transmit at about λ4900, the sensibility curve of the plate-and-filter combination is very flat in this region and does not rise to any considerable extent until λ5000 has been passed. In consequence, neither of the nebular lines N_1 and N_2 is transmitted with appreciable intensity; the yellow photographs, when strong, are therefore a record of the luminosity distribution for radiation lying well to the red of the chief nebular line. The red limit of the combination is λ5900. The sensitiveness of the ordinary plates, on the other hand, extends to λ5200 or even λ5300, so that the violet photographs include the effect of the characteristic nebular lines.

Planetary Nebulæ N. G. C. 2893 and 3242. Both objects contain star-like nuclei surrounded by nebulosity, but with marked differences in structure. A factor of four to one in the exposure times gives closely comparable yellow and violet images, for the nebulosity as well as the nuclei. Little or no difference in distribution is noticeable, and both objects are relatively rich in yellow light.

Ring Nebula in Lyra. The great photographic activity of this object has long been known, but it was a surprise to find that a quarter of an hour was required to record on a yellow plate as much as was obtained on the violet in 15^s. The only comparable images at present available are faint. They show little if any difference in the color of the ring and the central star. Both are intensely blue or violet. As the exposure factor is eight or ten times that necessary for comparable images of an A_0 star, the color-index of the central star must be of the order of —1.5 or —2.0 magnitudes.



DISTRIBUTION OF VIOLET AND YELLOW LIGHT IN MESSIER 99[*]
A. Seed 27, Exposure 10^m. Violet Light.
B. Cramer Iso, Exposure 60^m. Yellow Light.

The Spiral Nebulæ Messier 51, 94 and 99. Here we have the most interesting results thus far obtained. The nuclei in all three cases are of great relative intensity on the yellow plates. Rough estimates of their color-indices are in accordance with the advanced spectral types which characterize the central portions of spiral nebulæ. The center of the great condensation at the extremity of the branch on the northern side of M 51 is also very yellow; but the minor condensations scattered along the branches of all three spirals are in many instances so deficient in yellow luminosity that they do not appear at all on the yellow plates or are lost on the background of faint nebulosity, which in places is of much the same intensity on both violet and yellow plates. The branches as a whole are relatively blue, but in many of the star-like condensations the more refrangible radiation is relatively very intense.

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[*] The original photographs show much detail that is lost in the reproduction.

In comparisons of the sort described, care must be taken to allow for differences in gradation on the two kinds of plates. This difference is frequently important, but for the plates in question the variation in the distribution of the luminosity is so pronounced that there is no mistaking the phenomenon.

FREDERICK H. SEARES.

SIX CEPHEIDS WITH VARIABLE SPECTRA.

Variations in the spectra of eleven Cepheid variables have been announced in recent communications.[1] A considerable number of spectrograms of these stars has been secured during the last two months, and in all cases the variations previously reported are confirmed. Several other Cepheids have been added to the observing program, in fact, all of the brighter ones; and to the list of known spectrum variables six more stars may now be added. In the following table the brightness at maximum and the range of variation are given in visual magnitudes. The photographic range has been measured for some of these stars and found to be nearly double the visual change. The total range of spectrum variation is probably larger in many cases than defined by the limits here given, as the plates are made without knowledge of the light maxima and minima and but seldom do the spectra coincide with the extremes of the range in brightness.

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[1] *Proceedings of the National Academy of Sciences*, **2**, 132, 136, 208, 1916.

Star	Magnitude at Maximum	Range of Variation	Period	Observed Spectrum Variation
W Sagittarii	4.6	0.8	7.595	F0–F9
Y Sagittarii	5.8	0.8	5.773	F4–G0
U Aquilæ	6.2	0.7	7.024	F6–G2
SU Cygni	6.5	0.7	3.846	A6–F7
η Aquilæ	3.7	0.8	7.176	F1–G0
T Vulpeculæ	5.5	0.9	4.436	A9–G1

Variations seem to be present in the spectrum of S *Sagittæ*, but the plates available at present do not give a large range. Small variations are also suspected for U *Vulpeculæ* and ζ *Geminorum*.

Harlow Shapley.

Note on Comet *a* 1916 (Neujmin).

Comet *a* 1916 was first observed photographically by M. Neujmin, of Simeis, Crimea, on February 25, 1916.

The first observation received at the Students' Observatory was one made on February 29th by Van Biesbroeck at the Yerkes Observatory. The next two observations received were made on March 3rd by Hartwig at Bamberg, and on March 7th by Aitken at the Lick Observatory. On the basis of these three observations, an orbit was computed by Mr. Jeffers, Mr. Pierce, and the undersigned. The resulting elements and an ephemeris extending until May 1st are published in *Lick Observatory Bulletin* No. 280.

This orbit is elliptic, the approximate period of revolution being 5.2 years. This period may be changed by a year or two after the comet has been longer under observation. The short period indicates that the comet belongs to the *Jupiter* group.

The comet passed closest to the Sun on March 11th at a distance of about 124,000,000 miles. The plane of motion is inclined to the ecliptic at an angle of about 10°. The eccentricity is about 0.55, the longitude of the ascending node 328°, the longitude of perihelion 161°, and the semi-major axis three astronomical units or about 279,000,000 miles.

The comet was discovered in the constellation *Cancer* and is moving southeast. It is receding from the Earth. On May 1st it will be 0.34 as bright as on March 3rd, at which time it was estimated to be of the 10.5 magnitude.

There is a possibility of the identity of this comet with Comet 1889VI. A comparison of the elements of *a*1916 with those of 1889VI shows that they agree in every element except ω, the angle between the ascending node and the line of apsides on the side towards perihelion. Perturbations produced by *Jupiter* on 1889VI in 1910, 1911, 1912 may have caused a change in ω large enough to make it the same as that of *a*1916. The computation of these perturbations is now being carried on at the Students' Observatory.

JESSICA M. YOUNG.

Students' Observatory,
University of California,
April 10, 1916.

[Note added May 22, 1916.]

The ephemeris above mentioned gives a position for the comet on April 20th which differs from an observation of the comet made by Dr. Aitken on that date by $6'.7$ in right ascension and $1'.5$ in declination.

The comet is still moving southeast. Its position on May 22nd is $11^h\ 15^m\ 42^s$ in right ascension and $-14^\circ\ 41'.1$ in declination. Its brightness on this date is 0.2 its brightness on March 3rd. It is moving at the rate of about $-12'$ per day in declination and $+2^m\ 17^s$ per day in right ascension.

JESSICA M. YOUNG.

APPOINTMENTS TO FELLOWSHIPS IN THE LICK OBSERVATORY.

Dr. Warren Kimball Green, for the past two years University Fellow in the Lick Observatory, has been appointed Martin Kellogg Fellow for the next academic year. Mr. Green received the degree of Doctor of Philosophy from the University of California in May, 1916. His thesis is entitled "*A Study of Certain Nebulæ.*"

Mr. Charles Donald Shane, A. B. 1915, has been appointed to a University Fellowship in the Lick Observatory. Mr. Shane was graduated with honors in astronomy from the University of California and is at present a Teaching Fellow in Mathematics in the University.

Mr. Roscoe F. Sanford, present Martin Kellogg Fellow in the Lick Observatory, has been appointed to a University Fellowship in the Lick Observatory for the coming year.

Mr. H. B. Wilcox, B. S. 1914, University of Minnesota, at present an assistant on the faculty of the University of Minnesota, has been appointed to a University Fellowship in the Lick Observatory for next year.

Miss Jessica M. Young, M. S. 1915, University of California, at present University Fellow in Astronomy in the Berkeley Astronomical Department, is spending the summer vacation at work in the Lick Observatory.

A NEW COMET.

On a photographic plate taken at Königstuhl, Heidelberg, on April 27, 1916, Dr. Max Wolf found a cometary object in the position R. A. $12^h\ 40^m\ 16^s$; Decl. $+ 2° 24' 0''$. Announcement of the discovery reached Lick Observatory on May 2nd, but the object is visible only in large telescopes and on the nights when the 36-inch refractor has been available for micrometer work the weather conditions have prevented observations.

According to an orbit computed by M. Van Biesbroeck, at the Yerkes Observatory, the comet promises to be of more than of ordinary interest, for the time of perihelion passage is given as July 27, 1918, the perihelion distance as 141 millions of miles, the eccentricity as 0.6147, and the revolution period as 7.81 years. If these values are approximately correct, it should be possible to observe the comet thru more than half of its entire revolution about the Sun. It should be noted, however, that the motion is now very slow, and the arc on which the orbit is based very short. Large corrections to the orbit elements may therefore be required when later measures become available.

The comet is moving slowly north and west in the constellation *Virgo*.

R. G. Aitken.

May 20.

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

SOUTHERN DOUBLE STARS.

It is a pleasure to note the attention that is being given to the observation and discovery of double stars in the Southern Hemisphere. Mr. Innes has long been recognized as the leader in this work, his discoveries reaching a total of nearly 1100 pairs, and his measures of known pairs being far more extensive than those of any other observer in the Southern Hemisphere. In *Circular No. 33*, of the Union Observatory, South Africa, recently distributed, the fifth series of "Measures of Southern Double Stars," made with the 9-inch Grubb refractor, is printed. The measures, by Mr. Innes and his associates at the Union Observatory, are made in the same manner as those in the four earlier series, each pair being measured on one night when east of the meridian and on another when west. If the agreement of the two sets is not satisfactory, two additional sets, similarly divided, are made. The eyes, while observing, are held parallel or perpendicular to the line joining the two stars. With these precautions it is hoped that systematic errors of measurement may, for the most part, be eliminated.

The five series of measures contain, in all, about 1500 pairs, many of them so close as to reach the limit of the theoretical resolving power (about 0″.5) of the telescope. This fact, and the statement by Mr. Innes, that there are only one or two nights a year when it is not possible to measure with ease pairs whose angular separation is 0″.90, provided the two components are sensibly equal in magnitude, testify to the favorable observing conditions at Johannesburg and also to the excellence of the telescope.

As in the earlier series, Mr. Innes appends notes to the present list of measures, which add decidedly to the value of the paper. Of special interest to the present writer is the statement that wide and easy pairs, like many of the *h* pairs, are not to be observed hereafter, since motion in such pairs "will be disclosed with accuracy and certainty by the examination under the blink-microscope of pairs of astrographic (or other) plates taken at different epochs."

It is to be regretted that the war has seriously affected the work of the Union Observatory, not only by removing to some unknown future date the completion of the large telescope partly constructed for it, but by leaving the institution short handed. "* * * at present the staff is reduced to Mr. Innes and Mr. Wood, with two lady assistants who do the clerical and meteorological work."

In addition to the five series mentioned above, *Circular No. 27* contains a series of measures made with the 9-inch refractor by M. J. Voûte, of the Cape Observatory, during two visits to Johannesburg early in 1915. M. Voûte used the reversing prism in his measures, as in his earlier work at the Leiden Observatory, his chief object being to determine whether the elimination of systematic errors by its use "is efficient under different conditions of the instrument and place of observation." His conclusion favors the use of the prism, the probable error of measure being decidedly reduced thereby.

Professor W. J. Hussey has also been making important contributions to our knowledge of southern double stars by his work with the 17-inch refractor of the La Plata Observatory. In Part II of Volume I of the *Publications of the Astronomical Observatory of the University of Michigan*, are printed two lists of new double stars (the first of which had also been printed in Tomo I of the *Publicaciones* of the La Plata Observatory) which, together, include 311[*] pairs, and also a list of measures of nearly 200 other double stars south of —17° declination.

Some of the stars in all three of these lists have been measured on one night only, and some of the new pairs in the first list (13th Catalog) have not been measured at all, because no micrometer was available at the time of their discovery. The great majority, however, have been measured on two or more nights each.

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[*] Mr. Innes points out that 17 pairs previously discovered and measured by other observers are included in the two lists. The 14th Catalog contains only 99 stars, there being no number 1621.

In general, the new *Hu* pairs are of the same character as those discovered by Mr. Hussey while at the Lick Observatory, about 57 per cent. of those in the first list, and 70 per cent. of those in the second falling within the limit of 2″ in angular separation. A considerable percentage, however, are relatively faint pairs with angular separation well above the limits of 5″ adopted in work at the Lick Observatory, the widest pairs being *Hu* 1349 and *Hu* 1555, with distances 8″.85 and 8.″74 and magnitudes 9.0–10.5 and 9.1–9.8, respectively.

It is to be hoped that the double star work at both of these southern observatories may be carried on vigorously.

R. G. AITKEN.

May, 1916.

STELLAR MAGNITUDES OF THE SUN, MOON AND PLANETS AND THE ALBEDO OF THE PLANETS AND SATELLITES.

In the March, 1916, number of the *Astrophysical Journal*, Professor H. N. Russell presents a careful discussion of all existing photometric data of the Sun, Moon and planets and a determination from these of the most probable values of the stellar magnitudes on the Harvard scale of these objects. A critical comparison of the seven series of observations of the relative brightness of the Moon at different phases is made, and a satisfactory representation by a mean light-curve of all the observations is obtained. Attention is called to the fact that the full Moon is 8.7 times brighter than the first quarter, and 10.0 times brighter than the last quarter.

As the value of the visual stellar magnitude of the Sun he adopts the simple mean of the determinations by Zöllner, Fabry, Pickering and Ceraski, whose observations altho obtained by very different methods are in remarkable agreement. The visual magnitude of the Sun on the Harvard scale is then —26.72 ±$0^m.04$. From the weighted mean of King's and Birck's observations, the Sun's photographic magnitude is —25.93. Its color index is therefore +$0^m.79$, in good agreement with King's value of $0^m.72$ for stars of Class G.

Stellar magnitudes of the planets are based chiefly on the very extended series of observations by Müller, which for the brighter planets are found to require a correction of approximately —$0^m.06$ in order to reduce them to the Harvard system. For *Uranus* and *Neptune* no correction appears necessary. King's observations of the photographic magnitudes of the planets have been adopted in the present work.

Determinations of the stellar magnitude of the mean full Moon made by different observers are quite discordant and the value of this important constant is still subject to considerable uncertainty. For its value he has adopted the weighted mean of five series of observations, excluding all those which were obviously affected by systematic errors.

A second paper by the same author appearing in the *Astrophysical Journal* for April, 1916, is devoted to the determination of the albedo of the Moon, planets and brighter asteroids and satellites, on the basis of their adopted magnitudes, and to a discussion of the material bearing upon the albedo of the Earth.

Accepting Bond's definition of "albedo" as the ratio of the amount of light reflected in all directions by a sphere, to the total incident light when the sphere is illuminated by parallel rays, it is shown that the albedo may be expressed as the product of two factors. One of these depends only upon the law of the variation of the planet's light with phase, while the other factor (p) is the ordinary reflecting power (frequently called albedo), or the ratio of the observed brightness at full phase to that which would be obtained by replacing the planet by a flat disk of the same diameter as the planet.

A few values of the stellar magnitudes (m), reflecting power (p), visual albedo, color index, and photographic albedo are here given for the objects which are of general interest:

Object	*m*	*p*	Visual Albedo	Color Index	Photographic Albedo
Moon	—12.55	0.105	0.073	+1.18	0.051
Mercury	— 2.94	.164	.069	......	.....
	— 2.12	.077	.055	......	.....
Venus	— 4.77	.492	.59	+0.78	.60
Mars	— 1.85	.139	.154	+1.38	.09
Jupiter	— 2.29	.375	.56	+0.50	.73
Saturn	+ 0.89	.420	.63	+1.12	0.47
Uranus	+ 5.74	.42	.63	......	.....
Neptune	+ 7.65	.49	.73	......	.....

The values of *m* are for mean opposition, except those for *Mercury* and *Venus*: they are for mean distance from the Sun and unit distance from the Earth. Two sets of values are given for *Mercury*, computed respectively by Müller's linear empirical formula, and by his quadratic formula.

The results for the brightness of the Earth and its stellar magnitude are deduced from Very's recent observations of the intensity of the earth-shine on several different assumptions regarding the variation of the Earth's brightness with phase. On the assumption that this variation is the same as that for *Venus*, the stellar magnitude of the Earth as seen from the Sun is —3.8, its reflecting power (*p*) 0.37 and its visual albedo 0.45. Very's value of the Earth's albedo, 0.89, is shown to result from the use of Zöllner's value of the Moon's "true albedo" instead of its "apparent albedo." When this correction is made, Very's computation gives for the Earth's visual albedo 0.49, a result which instead of being inconsistent with Abbot's value of the solar constant, is actually in good agreement with it.

Professor Russell repeatedly calls attention to the urgent need of further observations of these fundamental photometric constants with modern precision, a piece of research which he says "would well repay the undivided attention of a competent observer for a considerable time."

J. H. Moore.

May, 1916.

THE EXTENSION OF THE SPECTRUM IN THE ULTRA VIOLET.

The light vibrations which affect our eyes or which are used in the ordinary processes of photography form only a few octaves, if we may borrow the term, in the extended gamut of ether vibrations, and all explorations which extend our knowledge of these vibrations beyond the red or below the violet of our ordinary spectrum possess a very great theoretic interest and may eventually prove to be of great value in spectroscopic theories of the constitution of matter.

The gradual process of exploration which has extended our knowledge of the spectrum below the limit of the human eye in the violet (wave-length about 4000 A) forms, with its record of successive obstacles overcome, one of the most interesting recent chapters of experimental research.

With glass prisms and lenses the lower limit of the spectrum was first pushed to about 3000 A; at this point glass becomes opaque to these short vibrations, and the next step was to use quartz prisms and lenses or reflecting gratings, by means of which the lower limit was reached at about 1850 A. Below this point not only does the gelatine of the ordinary photographic plate become opaque, but even a few inches of air cuts off these short waves as effectually as a screen of metal, and such substances as quartz and fluorite rapidly lose all power of transmission. This obstacle was in turn overcome by Schumann, who, by the invention of a special photographic plate very deficient in gelatine and by exhausting the air from his apparatus, was enabled to record spectral lines of as short a wave-length as 1250 A; at this point he was stopped by the opacity of the fluorite of which his lenses were made.

Professor Theodore Lyman was able, by employing a reflection grating and by filling his spectrograph with hydrogen gas, to reach the extremely short wave-length of 900 A in 1914. His paper in the *Astrophysical Journal* for March, 1916, of which this is a brief abstract, describes his further experiments in this interesting line of research. Finding that hydrogen, in its turn, had become opaque as far as wave-lengths shorter than 900 A were concerned, he turned his attention to helium, and by using this gas and by certain improvements in his apparatus he has succeeded in reaching the phenomenally short wave-length of 599 A, the present "farthest south" in this field of investigation.

Aside from the precautions which must be taken to render the apparatus leak-proof and to secure purity in the gases employed to fill the spectrograph, when one considers that each separate plate must be sealed inside the spectrograph, the air exhausted, the instrument filled with helium, and that then the apparatus must be taken apart to get out the plate after the exposure has been made, one obtains perhaps a slight idea of the difficulties of spectrum exploration in this region.

Only a few of the lines found have been identified with any certainty; a puzzling aspect of the results is that many of the strongest lines appear to be about equally strong in nitrogen, helium or argon, and are perhaps to be attributed to some subtle impurity.

The X-rays have a wave-length of the order of one angstrom; there is thus a gap of about 600 A between the wave-length of the X-rays and the limit reached by Lyman, who believes that this gap may be further shortened by purely spectroscopic means. It will certainly be a discovery of great interest when the point of transition shall be reached between the X-ray, to which many solids are apparently as transparent as is glass to ordinary light, and these short light-waves, to which a slight thickness of air or a half millimeter of quartz appears as effectually opaque as an equal thickness of steel.

H. D. Curtis.

A Variation in the Solar Rotation.

In the *Astrophysical Journal* for March, 1916, Professor Plaskett gives the results of his investigations on the rotation period of the Sun made at Ottawa in 1915. The method followed the general lines suggested in the conferences of the

International Solar Union, and the plates were grouped in point of time in such a way as to give data for the detection of variations in the rotation period of the Sun, whether of short or long period.

No evidence was secured which would warrant the assumption of a very short period variation in the solar rotation. The results, however, seem to point with considerable definiteness to a periodic variation in the speed of solar rotation at the equator with a period of roughly one month, and a range of about 0.15 kilometer per second. With regard to a secular change in the time of rotation the angular speed of rotation found from the 1915 results is 13°.83 per day, while the 1913 results gave a value of 14°.14 per day, apparently indicating that there had been a real change in the interim. The conclusion reached from a discussion of results secured at Ottawa and elsewhere is that since 1906 the equatorial rotation value has been slowly falling from 2.050 to 1.950 kilometers per second.

Tho such a result seems at first sight incomprehensible in a body so enormous as the Sun, one must remember that the phenomena are doubtless associated with a relatively thin surface layer, a layer which we know from sun-spot and other spectroscopic observations is rotating at different speeds from the equator of the Sun to its poles with occasional abnormal values and vagaries which still await adequate explanation. Some discussion is made in the paper quoted, showing the possibility of a physical explanation of such a variable velocity in accordance with Professor Emden's solar theory. A surface layer which shows so remarkable a change in its behavior as that exemplified by the difference between the epochs of sun-spot maximum and sun-spot minimum might well be expected to show similar abnormalities in its apparent speed of rotation.

H. D. Curtis.

May, 1916.

The *Astronomical Journal* Nos. 686-687 contains the definitive orbit of Comet 1855 II, by Georges van Biesbroeck, of Yerkes Observatory. As the comet was observed for only fifteen days but fifty determinations of position were available; the resulting elements satisfy all the observations well; an elliptic orbit is indicated with a period of several hundred years. The orbit shows some resemblances to that of the first comet of 1362, and a rediscussion of the Chinese observations of the latter comet is made in the endeavor to connect the two bodies as apparitions of the same comet, tho it is pointed out that the comet of 1362 was a striking object, while that known as 1855 II was barely visible to the unaided eye. The author comes to the conclusion that the identity of comet 1855 II with that of 1362 can not be considered as in any way proved.

REVIEW

TWO BOOKS ON METEORITES.

Students of meteorites will be interested in two volumes by Dr. Farrington, Curator of Geology in the Field Museum of Natural History, Chicago, which have appeared recently.

A *Catalogue of the Meteorites of North America* was issued a few months ago as Volume XIII, *Memoirs of the National Academy of Sciences*; 513 quarto pages of text, and 36 full-page sectional maps of North America. It treats of 247 objects or "falls" recognized by Dr. Farrington as *bona-fide* meteorites up to January 1, 1909. Of the 247, the iron meteorites number 161, the iron-stone meteorites 10, and the stony meteorites 76. Of the three kinds, 3 iron, 1 iron-stone, and 56 stone meteorites were actually seen to fall, but Dr. Farrington is convinced that the remaining 187 "finds" represent real "falls." Doubtful cases have been excluded. The phenomena of each fall and find, the shape, size, chemical composition, and mineralogical structure of each object, are described in good fullness, but completeness is obviously impossible in the cases which include many specimens in one fall or find. The Canyon Diablo group, for example, includes thousands of meteorites of a great variety of forms and sizes, and the author necessarily limited the text to such physical and chemical descriptions of selected specimens as would set forth the characteristics of the great group. Following the data for each meteorite is its bibliography; the author has aimed to give the reference for every paper which makes an appreciable contribution to the subject, but unessential papers are not listed. This volume represents an enormous amount of labor in collecting, reading, compiling, abstracting, editing. Good judgment was demanded constantly. The work appears to have been done thoroly and intelligently.

Dr. Farrington makes interesting comments upon the distribution of the 247 meteorites:

> Considering the province of North America as a whole, the distribution of known meteorites is most abundant in the eastern United States and in Mexico. Few meteorites are known in British North America and the western United States. There can be little doubt that the apparent scarcity in the localities indicated is largely due to lack of observers, as the writer has elsewhere urged. It is not safe, however, to ascribe too much to this cause, since areas equally populated show great discrepancies in the number of their meteorites. One of the best illustrations of this is the state of Illinois. This is an area of 56,000 square miles in which there are no known meteorites. The greatest massing of meteorites in the whole province of North America occurs in the region of the southern Appalachians, where the states of Kentucky, Virginia, Tennessee, North Carolina, Georgia, and Alabama adjoin. A circle with a radius of 300 miles drawn about Mount Mitchell, North Carolina, as a center, will include nearly half of the known meteorites of North America. Twenty-five of these, or nearly half of the known falls of the continent, are observed falls, and it would seem possible at first thought that many of the meteorites in this area might have come from a single shower. This would reduce the number, but the writer has made a careful study of the history of each meteorite and its geographical relation to those of similar character without finding any support for such a view. Not only does the area contain a large number of observed falls, but the finds embrace a variety of types larger than any known to be produced by a single shower. * * * As regards population in the area, conditions are only moderately favorable, since the area is not very thickly settled. The climate of the region is moist, the average yearly rainfall being 50-60 inches, so that a relatively rapid disintegration of iron meteorites might be expected. Yet in spite of so many conditions unfavorable to their occurrence in large numbers, meteorites are superabundant in this area. This seems to leave little doubt that some force tends to bring about their concentration here. It is noteworthy that this region includes the

highest summits of the Appalachians, and this suggests either the presence of an extra-gravitational force or that a purely obstructive effect has been exerted by the high peaks. Studies of the gravitational effects of mountain masses indicate no force seemingly sufficient to affect the fall of a meteorite, though some such force may exist. Magnetic influences may also be suggested. Next to the massing of meteorites about the southern Appalachians, the most striking grouping seems to be within the borders of Kansas. Within the area of this State, about 82,000 square miles, 15 meteorites occur. Of these, four are observed falls. Those of the western part of the State are all stones, and an effort has been made to show that they may have been the result of a single shower, but the history and characters of the meteorites, to the writer's mind, negative this view. The soil of the western part of Kansas is especially favorable to the finding of meteorites, as it contains few terrestrial rocks, but this advantage is perhaps neutralized by the scantiness of the population. The climate is dry, thus tending to the preservation of meteorites. The region is not itself mountainous, but is elevated and within a few hundred miles of the mountain masses which culminate in Pike's Peak. * * *

The three greatest meteorite showers of North America have all occurred within the state of Iowa, two of them within 65 miles of each other, the third 130 miles distant from either. * * *

It is evident that the distribution of the localities from which meteorites are known, or what may be in short known as the distribution of meteorites, will be affected by at least four terrestrial factors: (1) density of population, (2) character of population, (3) climate, and (4) character of soil. Density of population will increase the number of meteorites known from a region, because the greater the population the greater the number of observers and the more numerous the chances both that the meteorite will be observed when it falls and that it will be found after it has fallen. As regards character of population, a high order of intelligence is favorable not only to the observation but to the preservation of meteorites. The writer has elsewhere called attention to the fact that the distribution of meteorites on a map of the world is almost exactly that of the Caucasian race. This seems to prove quite conclusively that the distribution of meteorites is largely dependent on the degree of civilization attained in a region. That this factor is more important than density of population is shown by the fact that no meteorites are known from China in spite of its immense numbers of people. In the province of North America it is hardly likely that the different degrees of intelligence existing in different regions would exert any discernible influence on the number of meteorites known. As regards climate, aridity may be doubtless considered favorable and humidity unfavorable to the preservation of meteorites. In a humid climate the iron meteorites disintegrate much more rapidly than in an arid climate, and to a certain extent the same is true of stone meteorites.

As regards character of soil, it is obvious that soils free of rocks would be most favorable to the finding of meteorites. The existence of such soils in Kansas and Texas has led to the discovery in those regions of meteorites that would probably have been overlooked in stony localities. An iron meteorite is, of course, more likely to attract attention in any soil than a stony meteorite, but the latter is quite likely to be overlooked in stony soils. From the above it appears that the most favorable terrestrial conditions for the finding of meteorites are those of a dense, intelligent population living in an arid climate and upon a pebbleless soil. Such conditions are not likely to exist together, but now one and now another will predominate in any given region. To a certain degree the absence of one is likely to offset the presence of another, but where several of these conditions are lacking and a preponderance of meteorites occurs other reasons must be sought. The eastern states of the United States as compared with the western states possess a relative dense population, but a moist climate and rocky soil. Canada has a scanty population, a moist climate, and rocky soil. Mexico has the advantage of an arid climate but the disadvantage of a scanty and illiterate population, and a more or less rocky soil.

The second volume by Farrington is on *Meteorites: Their Structure, Composition and Terrestrial Relations;* octavo, pp. 233 + x and one chart.* It is in the nature of a general treatise on the subject, prepared from the viewpoint of the mineralogist rather than of the astronomer. The reviewer acknowledges the inadequacy of what he is writing concerning the book on that account. However, the book has many points of contact with astronomical problems, and is of interest to all students of nature.

The author describes three classes of meteorites—stone, iron-stone, and iron meteorites, which pass from one class to the next by almost insensible gradations—and explains how specimens usually may be distinguished as real meteorites or as of terrestrial origin. "No single criterion can be given for distinguishing meteorites from masses of terrestrial origin. Only by combining several features can the positive determination of a meteorite be made." Even so, it seems, there must be cases in which the meteoric origin cannot be ascertained with certainty. "So far as the iron meteorites are concerned, the presence of nickel is essential. No iron meteorites are known without nickel. Yet this alone does not prove meteoric origin, since terrestrial nickel-irons are known. Terrestrial nickel-irons, however, have a percentage of nickel either lower (3%) or higher (35%) than that of meteorites, so that a percentage of nickel between 8% and 20% is a pretty sure indication of meteoric origin." Other lines of evidence have somewhat similar values, and must be treated with circumspection.

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*Published by the author.

We quote a few specially interesting facts from the book:

> Of about 700 meteroites now recognized, only about one-half were actually seen to fall. * * * Of about 350 observed falls only 10 have been of iron meteorites. On the other hand, among meteorite "finds," the iron meteorites largely predominate. This is chiefly for the reason, doubtless, that the iron meteorites * * * attract the attention of the ordinary observer much more quickly than the stone meteorites. The latter show to the casual observer no striking differences from the terrestrial rocks, and are thus usually overlooked.
>
> No meteorite fall has ever been positively known to have been destructive of human life. * * * Perhaps the most narrow escape which has ever been experienced was that of three children in Braunau at the time of fall of that meteorite in 1847. This meteorite, an iron weighing nearly 40 pounds, fell in a room where these children were sleeping and covered them with debris, but they suffered no injury.

About 20 of the most interesting observed falls of meteorites are described at some length. The part played by our atmosphere in resisting the passage of meteorites is discussed, in somewhat general terms, to about the extent that the reader of popular astronomical articles will desire, but not to meet the needs of the student of the subject.

The times of fall, with reference to years, months of the year, and hours of the day, are discussed, but unfortunately the value of the discussion is reduced by the great number of errors in the summations (page 41), as well as by weakness in the astronomical aspects of the problems. We quote from p. 44: "All meteorites which move in orbits which are parabolic about the Sun have a velocity of 26.16 miles per second." This sentence could easily puzzle many readers, but one who already understands the subject can interpret the author's idea. It seems to mean that a meteoric body traveling around the Sun in a parabolic orbit which intersects the Earth's orbit will at the point of intersection have an orbital velocity of 26.16 miles per second; and, therefore, a "parabolic" meteorite (a body that comes down thru our atmosphere) possesses intrinsically that velocity. One ought to recall that as the Earth's distance from the Sun varies by as much as three million miles in the course of a year, so the parabolic velocity of a meteorite will vary correspondingly. And should the reader be left with the thought that the orbits of meteoritic bodies are parabolic in general? The work of H. A. Newton and of W. H. Pickering is counter to the idea. The author refers to the opinions of these investigators, but much later in the book, on page 213.

The author's description of meteoritic showers records many interesting facts. "In each of the showers of Pultusk and Mocs more than 100,000 stones fell. In the shower of Holbrook, 14,000 stones fell, and in that of L'Aigle 2–3,000." "All observed showers have been of stones, but the finding of numerous individuals of iron in single localities such as Toluca and Canyon Diablo indicates that showers of meteoric irons sometimes take place also."

"The largest individual meteorite known is one of the Cape York, Greenland group," an iron meteorite weighing 36½ tons, brought home by the Arctic explorer Peary and deposited in The American Museum of Natural History, New York City.

Chapters of the book are devoted to Forms of Meteorites, Crusts of Meteorites, Veins of Meteorites, Structure of Meteorites, Composition of Meteorites, Origin of Meteorites, Terrestrial Rotations and Meteorite Collections.

Twenty-nine chemical elements have been found in meteorites in quantities sufficient for accurate study.

The author reviews the conventional ideas of the origin of meteorites, but wisely comes to no definite conclusion.

The great collections of meteorites in Europe and America are located and each given a sentence or two of description. The principal collections in the United States are at Yale University, Harvard University, Amherst College, the American Museum in New York, the National Museum in Washington, and the Field Museum in Chicago. The author states that the Chicago collection is "now the largest in the world. This collection was inaugurated in 1894 at the time of the founding of the Field Museum by purchase of collections from George F. Kunz and Ward's Establishment. In 1912 the private collection of Professor Henry A. Ward, numbering over 600 falls (and finds), was added to the collection, and thus the most representative series of meteorites in the world was secured." The growth of American collections has been remarkable. It is hoped that they will be made the subjects of fruitful study, with a view of contributing their share in solving the many problems of meteors and meteorites still before us.

W. W. CAMPBELL.

GENERAL NOTES.

Meeting of the Astronomical Society of the Pacific at San Diego.—The Astronomical Society of the Pacific will hold a meeting at San Diego in August in conjunction with the first meeting of the Pacific Division of the American Association for the Advancement of Science, of which it is a constituent member.

The opening session of the Pacific Division A. A. A. S. will be held on Wednesday, August 9th, at which time the President, Dr. W. W. Campbell, will give an address on the subject of "What We Know About Comets." Separate sessions of the various constituent societies will be held on the two following days and on Saturday, if necessary. The latter day, however, is mainly reserved for excursions. A pamphlet giving full information regarding the meetings, rates of transportation, hotel rates, etc., will be mailed to all members in the Pacific area at a later date.

The program committee for the astronomical meetings, Messrs. Aitken, Leuschner and Seares, request that members planning to present papers send the titles to the committee as soon as possible, together with a statement of time needed for presentation and whether or not lantern slides will be used. Abstracts of papers should be in the hands of the committee early in July and certainly not later than July 20th. Authors are urged to make the abstracts intelligible and interesting to non-professional readers, as it is planned to print many of them in the daily press.

The Difference of Longitude Between Paris and Washington.—A definitive discussion of the determination of the difference of longitude between Paris and Washington in 1913-1914 by means of radio-telegraphic signals exchanged between Arlington, Va., and the Eiffel Tower, Paris, has been completed by M. Renan, of the Paris Observatory staff, and the results are communicated by the director, M. Baillaud, in the *Comptes Rendus,* for February 14, 1916.

In the first period of observation, beginning October 27, 1913, and extending to the end of December, complete observations at both stations, with successful exchange of signals, were secured on seven nights. On fourteen other nights signals were exchanged, the time observations failed to be secured at one or the other station. These are called incomplete observations.

In the second period, beginning January 21, 1914, and extending to early March, complete observations were secured on ten nights, incomplete on twenty nights. Between the two series the observers exchanged stations. It was found that the chronometers were so accurately rated that the incomplete observations could be used as well as the complete ones. The final results are:

FOR THE COMPLETE SERIES.

First period	5^h	17^m	$36^s.62$
Second period	5	17	36 .84
Weighted mean	5	17	36 .74

FOR ALL THE SERIES.

First period	5^h	17^m	$36^s.62$
Second period	5	17	36 .84
Weighted mean	5	17	36 .76

The last result is adopted, and substracting from it $0.^s09$ to reduce to the fundamental meridians of the two observations, we have for the difference of longitude

$$5^h\ 17^m\ 36^s.67$$

A preliminary discussion by the American observers gave the value $5^h\ 17^m\ 36^s.66$, and, like the figures here given, showed a difference of $0^s.22$ between the results for the two periods. In view of the difficulties attending the transmission of signals this is not considered excessive.

The date in the American Ephemeris for 1916, based on earlier determinations by other methods give $5^h\ 17^m\ 36^s.71$ for the difference in longitude.

From the report of the annual meeting of the National Academy of Sciences, printed in *Science* for May 5, 1916, we take the following:

REPORT OF THE COMMITTEE ON THE HENRY DRAPER FUND.

Four members of the committee, without consulting the fifth member (Professor Michelson), recommended that the Henry Draper Gold Medal be awarded to Professor A. A. Michelson, of the University of Chicago, for his numerous and important contributions to spectroscopy and astronomical physics.

It is impossible in the brief space of this report even to enumerate Professor Michelson's major services to science. These include the precise determination of the velocity of light; the well-known experiment (with Professor Morley) on ether drift; the measurement of the absolute wave-length of light involved in his determination of the length of the standard meter; the measurement of tides in the body of the Earth with new apparatus of extraordinary precision; and the invention of the interferometer, the echelon, and other instruments of prime importance to the student of light. He has also constructed a ruling machine yielding diffraction gratings of the longest size and the highest resolving power yet attained, and carried on a multiplicity of researches of wide range and fundamental significance.

The same report shows that grants have been made to astronomers from trust funds held by the Academy as follows:

From the Draper Fund, $250 to Professor Philip Fox, Dearborn Observatory, to apply toward the cost of a machine for measuring astronomical photographs.

From the Watson Fund, $500 to Professor John A. Miller, Sproul Observatory, for the measurement of stellar parallax plates already taken; and $300 to Professor H. C. Wilson, Goodsell Observatory, for the measurement of positions of asteroids on plates already taken.

From the J. Lawrence Smith Fund, $300 to Professor S. A. Mitchell, Leander McCormick Observatory, to continue the work on paths and radiants of meteors.

In his report of the Harvard College Observatory for the year ending September 30, 1915, recently distributed, Director E. C. Pickering calls special attention to the generous support given to the Observatory for nearly thirty years by the late Mrs. Anna Palmer Draper. By her will, Mrs. Draper placed the Henry Draper Memorial of the Observatory upon a permanent foundation.

Among other items of interest in the report we note specially the fact that Miss Cannon has completed the first step in the formation of the *New Draper Catalog*—the classification of the spectra. In all, 233,050 spectra, including stars to about 9.0 magnitude in the entire sky, have been classified.

A note in *Popular Astronomy* states that the Van Vleck Observatory of the Wesleyan University, Middletown, Conn., is now practically completed. Professor Frederick Slocum is the director.

Dr. Frank Schlesinger, director of the Allegheny Observatory, was elected to membership in the National Academy of Sciences, and Dr. Forest Ray Moulton, professor of astronomy in the University of Chicago, to membership in the American Philosophical Society, at the recent annual meetings.

Dr. William Frederick King, chief astronomer of the Canadian Government, superintendent of the Geodetic Survey of Canada, and director of the Dominion Astronomical Observatory at Ottawa, died on April 23rd, at the age of sixty-two years.—*Science*.

In the Days of the Daguerrotype (Occasion—the taking of a portrait in Mérida, Yucatan, in the year 1842, by the explorers Stephens and Catherwood).

"* * * The plate was now cleaned, put into the box, and the light shut off. Now came a trying time for the young lady. She must neither open her lips nor roll her eyes for one minute and thirty seconds by the watch. This eternity at length ended, and the plate was taken out.

"So far our course had been before the wind. Every new formality had but increased our importance in the eyes of our fair visitors and their respectable companions. Mr. Catherwood retired to the adjoining room to put the plate in the mercury bath, while we, not knowing what the result might be, a little fearful, and neither wishing to rob another of the honour he might justly be entitled to, nor to be dragged down by another's failure, thought best to have it distinctly understood that Mr. Catherwood was the *mæstro*, and that we were merely amateurs. At the same time, on Mr. Catherwood's account, I took occasion to suggest that the process was so complicated, and its success depended upon such a variety of minute circumstances, it seemed really wonderful that it ever turned out well. The plate might not be good, or not well cleaned; or the chemicals might not be of the best; or the plate might be left too long in the iodine box, or taken out too soon; or left too long in the bromine box, or taken out too soon; or a ray of light might strike it on putting it into the camera or taking it out; or it might be left too long in the camera or taken out too soon; or too long in the mercury bath or taken out too soon; and even though all these processes were right and regular, there might be some other fault of omission or commission which we were not aware of; besides which, climate and atmosphere had great influence and might render all of no avail. * * * The result, however, was enough to induce us never again to adopt prudential measures, for the young lady's image was stamped upon the plate, and made a picture which enchanted her and satisfied the critical judgment of her friends and admirers."

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Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

	4 pp.	8 pp.	12 pp.	16 pp.
50 copies, without covers	$2.00	$4.00	$5.50	$7.00
50 copies, with covers	4.00	6.00	7.50	9.00

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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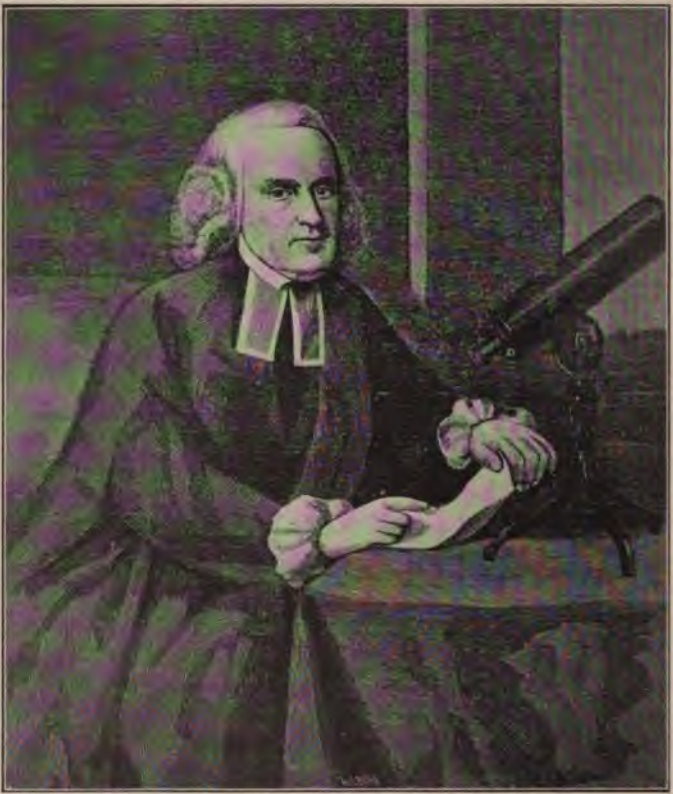

JOHN WINTHROP.

Reproduced by Mr. Leon Campbell, of Harvard College Observatory, from a steel engraving in Winsor's Memorial History of Boston.

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JOHN WINTHROP (1714-1779), AMERICA'S FIRST ASTRONOMER, AND THE SCIENCE OF HIS PERIOD.

By Frederick E. Brasch.

To many of the present generation of astronomers, the history of science, and more particularly the history of astronomy in this country before 1840 (the year in which the American Association for the Advancement of Science was organized), possesses something of the spirit of the early renaissance of Europe. In all probability, their historical perspective is bounded by the year 1846, in which Harvard College Observatory was founded.

If one reviews the records of the past closely, there is no need to wonder that our knowledge is deficient in this respect, for the study of the history of scientific thought during the colonial period has practically been neglected. However, there are several very excellent treatises upon the individual sciences; namely, E. P. Merrill, History of American Geology[1]; Dr. E. F. Smith, Chemistry in America[2]; Dr. Florian Cajori, History of the Teaching of Mathematics in the United States[3]. In the history of astronomy, several astronomical writers[4] have made brief references to the colonial period. For a comprehensive survey of the whole field of American science George Brown Goode[5] (1851-1896) is practically our first historian of science in this country.

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[1] Smithsonian Report, 1904. U. S. Mus.

[2] "Chemistry in America," Appleton, 1914.

[3] Bureau of Education, Washington, 1890.

[4] Safford, Newcomb, Holden, Young and See.

[5] "History of Science in America." Nat. Mus. Report, 1897, Pt. II, Washington. 1901.

While it is true that the period of early settlement of community life had not the spirit, resources, and inclination for investigations in the phenomena of nature, yet the history of that most critical and interesting period of colonization contains many records of the attempts to advance science, especially astronomy. In one form or other astronomy seems to have been the favorite subject of abstract and practical thinking in the Colonies, primarily for the vain art of astrology and for almanac construction. There are evidences also that the "learned ministry" were assiduously engaged in computing eclipses, and in observing other celestial phenomena. In one most curious record[6] we find a Rev. Samuel Danford of Roxbury, New England, who published in 1665 "Astronomical Description of the Comet of 1664," with brief theological applications, and in the church records he has left various memoranda such as the following: "Anno 1652, 9th day, 10th month. There appeared a comet in ye heaven in Orion, which continued its course tow^{d} or zenith f^{r} space of a fortnight, vis till Mr. Cotton's death."

A good introduction to the spirit and progress in that age may be obtained by studying it in terms of the parallel period in Europe. Colonial science was born of European thought and nursed by English scholars, due to the fact that the colonists carried over with them the sciences and culture of the old world.

When Harvard College was founded in 1636, making Boston the earliest colonial intellectual center, the first century since the publication of the "De revolutionbus orbium celestium" by Copernicus, had not passed; Kepler had announced his three laws of celestial mechanics; Galileo had made his discoveries; but Newton was not born, and the Greenwich and Paris observatories had not come into existence, nor had the great academies of sciences in England, France, and Italy been incorporated.

In the American colonies, the intellectual life—and its contribution to the value and realism of scientific thought—was still firmly involved in the romantic and historical traditions of the land. The pre-colonial or puritanic epoch was clothed in the spirit of mysticism and the superstition of Europe, and not until the early 18th century do we find any marked advance towards empirical reasoning in scientific knowledge.

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[6] "Memorial History of Boston." 4, 490.

Science, however, did not rest long under the yoke of the theological speculations of that epoch, for it soon appeared as an integral part of the growing life of progress. This more progressive and liberal attitude toward the problems of science had its formation, not so much in the opposition of the old puritanic theology, as in the development of the economic life of the growing communities. The westward movement, the economic expansion, and the cultivation of the arts and sciences had a correlated interdependence as well as a parallel history in their development.

Naturally the first impulse of the growth of this character was felt in the local centers of learning. Therefore, Harvard College, founded as an institution for the Christian ministry, again, after a hundred years of struggle, began to take on fresh life; introduced new and more extended courses in science, and vitalized her methods of instruction. During this second period —beginning with 1736—the critical point in the history of science teaching was reached. All instruction in Latin, Greek, logic, metaphysics, mathematics, and natural philosophy was divided into groups, commonly known today as departments, and for the first time the last two groups were established as a separate and endowed professorship. This innovation in science instruction was liberally endowed by an English merchant-banker, Thomas Hollis, and was known as the Hollis Professorship of Mathematics and Natural Philosophy. The first occupant of this chair failed, and John Winthrop was appointed.

John Winthrop was born in Boston, December 19, 1714, of the fourth generation of the long line of Winthrops honored in history. Several of the Winthrops of colonial times were patrons of the sciences, but none employed such high talent so exclusively in this field of activity, nor attained so great esteem, as did the subject of this sketch. At present little is known of his early life, except that during his college career (1728-32) he was recognized as an exceptionally brilliant student. He immediately developed a great fondness for mathematics and astronomy, which later became his life work. Winthrop at the age of eighteen years was graduated from Harvard College in 1732 at the head of his class. For the next six years little seems to be known of him, and not until 1738,—when a vacancy was created in the Hollis Professorship of Mathematics and Natural Philosophy,—do we find our young scholar before the committee from the overseers of the college to be examined upon his proficiency in mathematics. Another committee was to examine Winthrop for any possible contamination of heresy and the status of his liberal ideas, which it was feared might prove too dangerous for Harvard at that period. However, this action was finally voted down. According to the custom of the day, his election was approved, and at the age of twenty-four years he was formally inaugurated and launched upon a successful career, extending over more than forty years of continuous service to his *alma mater*. He entered upon his work with zeal and activity, and with the fullest understanding of the large task before him.

As has been pointed out, the science of the colonial period was transplanted English science or thought, largely due to the fact that English methods and books of instruction prevailed; and also, the Royal Society acted as an authority and sponsor of the colonial scholarly attainments. But it will be shown that the work and influence of John Winthrop established for the first time America's independence in scientific development, and also gave to Harvard College her early prominence in scientific investigations. Thus, not alone did he lay the foundation of Harvard's supremacy in science, but earned the rank of America's first astronomer and scientist, thereby giving to his name a larger place in the history of American science.

Winthrop's influence was probably greater than that of any other man of culture thruout the Colonies. Both Franklin and Count Rumford owe much to him. The Royal Society early recognized his worth, as did also the astronomers-royal, Bliss and Maskelyne. There seems to be no record of any description showing whether he was in correspondence with his co-worker in a common field, David Rittenhouse of Philadelphia, his junior contemporary, altho both were elected members to the American Philosophical Society in the same year and were mutual friends of Benjamin Franklin.

Winthrop's European contemporaries were Newton (1727), Halley (1742), Jean Baily (1793), Delambre (1822), and La Place, Lavoisier, Herschel, Kant, and Leibniz. These later men were at the zenith of their powers. The new astronomy was just being developed. At this period Herschel was engaged upon his famous study of nebulæ and double-stars, Kant and La Place in the study of cosmogony,—the origin of the solar system. All these discoveries were as yet unknown to Winthrop.

Few men have been so catholic in their taste as Winthrop, so far at least as astronomy is concerned. He was an excellent mathematician, astronomer, meteorologist and something of a geologist, equally learned and original. In the fullest sense of the term, indeed, he was a natural philosopher.

While Winthrop was primarily a teacher, yet his temperament and training enabled him to utilize every possible opportunity at his disposal for the good of science and society. Not only was he regarded as the greatest mathematician[7] of his age on this side of the Atlantic, but he was also equally keen as an observer of natural phenomena; accurate, methodical, and skillful. The demand upon his time as a writer and lecturer during his early career was heavy.

The documents still extant are evidence conclusive of his simple literary style, which is clear, lucid, accurate, and above all attractive. He was greatly admired by his students and fellow citizens for his admirable personal qualities, for his calm and dignified attitude toward his work, and his ideals for service to the community.

Winthrop was stimulating and inspiring, both as a teacher and lecturer. Count Rumford, who as a lad of seventeen was a student under him, says: "I made sufficient progress in Natural Philosophy under that excellent and happy teacher."[8]

Winthrop's influence upon Rumford, no doubt, had much to do in holding the affection of this exiled scholar for his native country. Count Rumford's success enabled him to endow a professorship in science at Harvard College and a research fund in the American Academy of Arts and Sciences, as a token of his regard for the young republic.

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[7] Mass. Hist. Soc. Collections, 1st ser., **10**, 159.

[8] Ellis, "Life and Work of Count Rumford," **1**, 7.

The requirements and duties for a professor at Harvard at that period left little time for Winthrop's private work. However, he did, with much zeal, perform what astronomic work was possible, to his great credit. This can best be understood by studying his results in the following references. The modern laboratory was not known then, but Winthrop possessed apparatus which will illustrate the fundamental facts of natural philosophy then known. "For Astronomy"[9], he says, "we had before been supplied by Mr. Hollis with telescopes of different lengths, one of 24 feet; and a brass quadrant of two feet radius, carrying a telescope of a greater length, which formerly belonged to the celebrated Dr. Halley. We had also the most useful instrument for dialing; and for surveying, a brass semi-circle, with plain sights, and magnetic needles. Also a curious telescope, with a complete apparatus for taking the difference of leveling. From a number of gentlemen of the province the following additions were received: a fine reflecting telescope of different magnifying powers, and adapted to different observations. Microscopes of the several sorts now in use; Hadley quadrant, fitted in a new manner, a nice variation compass, and dipping needles with instruments for the several magnetical and electrical experiments,—all new and of excellent workmanship,—and all destroyed in the burning of Harvard Hall in 1764."

From the ruins of this disastrous fire an appeal was sent out over the land, which in time completely supplied new sets of apparatus and instruments for experimental philosophy. Besides philosophical apparatus, the following instruments for astronomical work were secured almost immediately: Glasses for telescopes, globes, an orrery, Hadley quadrant, a telescope twenty-eight feet in length of the Huyghens type, and a reflecting telescope of the Gregorian type. Most of these instruments, with an electrical machine given by Benjamin Franklin[10] to the college, are still to be seen in the

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[9] Quincy, "History of Harvard University." 2. 482-3.

[10] Cajori, "History of Physics," note, p. 127.

Jefferson Physical Laboratory and the Observatory of Harvard University.

Winthrop's first authentic astronomical observation was made in 1739 on spots upon the surface of the Sun. There seems to be no printed record of the observation of these phenomena. However, a manuscript copy is treasured in the Harvard College Library.[11]

We now come to Winthrop's first important astronomic work, which began with the observation of the transit of *Mercury* in 1740 (April 27th). This may be taken as the first real evidence of efforts to promote astronomical science in the colony. Rittenhouse did not begin his work until 1768.

The transit of *Mercury* over the Sun is not of such great astronomical importance as that of *Venus*, but serves as a means of ascertaining the planet's position, by which its orbit can be improved.

Winthrop had accepted as his authority Halley's (then the leading astronomer of Europe) tables and ephemeris of planetary motion, which were in use. He was advised that the former part of this transit would be visible in his horizon, and therefore resolved to observe it with an instrument he already possessed; namely, the 24-foot Huyghens telescope.

The qualitative results are probably not greatly different from our present knowledge of such transits, but it is in the methods of arriving at these results that the vast improvements have been made. Without the modern clocks, chronographs and electric circuit breaks,—also firmly mounted telescopes with all the accessories,—it is to be wondered that Winthrop accomplished his task at all. There is something inspiring in the spirit and zeal with which such pioneering work is sometimes accomplished. And Winthrop, with his splendid scientific characteristics and thoro knowledge and understanding of the theory of planetary motion, accomplished his task with such a marked degree of success, that his work was accepted by the Royal Society of London and published in full in the *Transactions*. It also received favorable mention in the Memoirs of the Royal Academy of Science at Paris. Winthrop was thanked by the Royal Society and asked to continue his communications, which immediately gave him high rank and finally led to his election as a fellow.

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[11] Private letters from Librarian W. C. Lane.

About this time our young astronomer made a number of minor observations upon such phenomena as lunar eclipses, meteors, and the determination of longitude, which was a question not fully settled as yet. He was also greatly interested in lightning and its relation to electricity.

In treating of the next problem of interest to Winthrop, we come upon a subject of more than common interest to us, an untouched field at this period of colonial progress, for it had not assumed any definite scientific status,—that is, the science of meteorology. Boston, the metropolis of New England, had a population in 1740 of something more than 25,000 inhabitants, with a surrounding farming country fairly prosperous, but as yet not depending upon accurate forecasting of the climatic changes. For forecasting, methods of analysis and instruments were required. The latter were rare and expensive. Moreover, the value and function of systematic weather prognostication had not been clearly understood, either for economic or industrial purposes.

Winthrop in 1742 began his series of meteorological observations, which continued upward of twenty years. It is not known whether he had in mind the true function and value of the data secured, but his fidelity to a certain idealism in science enabled him to make his observations with devotion. His early observations, 1742-59, were more or less inaccurate, due, no doubt, to faulty exposure and the imperfections of the instruments of that period; but his later series, 1759-63, were of more value.

The following is a description of the thermometer used by Winthrop in the first series. The original manuscript is in the possession of the American Academy of Arts and Sciences:[12]

"My thermometer was of Mr. Hawksbee's make, filled with spirit of wine. Ye scale is divided into 100 parts, beginning from a certain point above marked 0 and ye 100th degree falls just above ye bulb of ye thermometer. Ye freezing point is numbered 65°. Ye divisions are upward to 8° above zero. Ye observations are expressed in the degrees with their decimal parts.

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[12] Report of the International Meteorological Congress, Chicago, 1893. Pt. II, Washington, 1895.

"The instrument shows the highest temperature but not the lowest, for it goes into the bulb. How it was adjusted in London I know not, but it appears to me yt ye freezing point is marked considerable too high, for having plunged ye bulb into a vessel of snow I found yt ye spirit fell down to 76°.5 and then rested."

In 1759 Winthrop secured a Fahrenheit thermometer, placing it on the north side of the house, and, fortunately, comparative readings were made between the two thermometers, which gave an opportunity for comparing one scale with the other. These records were continued by him until 1763, and since then have been maintained by others with more or less completeness to our present day.

The year 1755 was a memorable one to the inhabitants of New England, due to the occurrence of an earthquake of some severity. The study of this phenomenon called forth Winthrop's best endeavors and revealed at the same time a large and broad-minded scientist. As a theorist, he probably was more modern than he has been given credit for. His observations, deductions, and the theory he advanced, besides the theological implications, were given in two lectures in the Harvard Chapel before the students and faculty. These lectures were printed at the general desire of the community, and remain as perhaps the earliest classic of American scientific literature.

The whole treatise shows an exceptionally comprehensive study. It is also a curious intermixture of analytical chemistry, mineralogy, geology, and astronomy.[13]

Winthrop is often called our first seismologist.[14] He was the first in this country to apply true inductive methods to observations of the earth-movement, and to advance the theory that the disturbances of the earth-crust were in the form of waves, and transmitted a pendulum-like motion to buildings and objects on the surface. He was the first to apply computation to the phenomena, consequently discovering the analogy between seismic motion and musical vibrations; he also discovered the principle that the quicker the motion the shorter the wave length of the disturbance. His ideas on the nature of heat were new to the science of geology, especially relating to the internal actions of volcanoes and earth-movements.

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[13] Full reprint in *Bulletin of Seismological Society of America*, 6, 26-42, 1916.

[14] "National Biographies," (American), 7, 165.

In view of the fact that his period lacked trained men to observe and study such phenomena, and also lacked the instruments and methods for recording their effects, it is surprising that his deductions were so complete and accurate.

Winthrop's theological views, liberally interspersed with his scientific observations, were not unduly incongruous with the general spirit of science or scientific belief. While he may have separated the idea that such phenomena of nature as earthquakes were not the direct expression of the wrath of God, he did not completely abandon the dualistic doctrine held so tenaciously by the puritan inhabitants of old New England. This was one of the objects of his public lectures, —primarily to alleviate the fears, superstition, and ignorance concerning the significance of such phenomena, since the credulous puritans were not yet entirely ready for purely scientific explanations of natural phenomena.

Winthrop's next public work was two lectures upon comets, and in particular on the return of the comet (1682) better known as Halley's comet, which he was fortunate to observe, since it was the first predicted return of a comet. This lecture was also read in the Chapel of Harvard College, 11th of April, 1759, as part of the regular and assigned duty of the Hollis professorship. Winthrop first observed this comet on April 3d, after it had passed perihelion, and, like similar celestial phenomena, had caused much anxiety and speculation as to its meaning.

In the first lecture his introduction to the subject of comets is descriptive, showing the relation and differences between comets, fixed stars and planets. This is followed by a history of their discovery with various theories concerning their origin and nature, especially during the preceding two hundred years.

His own observations and theories are, however, well worth considering, in their relation to astronomic thought and its bearing upon history. Winthrop has revealed himself as a mathematical and theoretical astronomer, but he has also proved his ability as a capable and practical observer. He computed the orbital elements of one of the comets under observation during this period; and his work upon the geometrical demonstrations, suggested by Newton, concerning the ascent of the tails of comets received laudable notices from the Royal Society.[15] This paper, the original of which was in Latin, entitled "Cogitata de Cometis"[16], was communicated to the Society by Dr. Franklin in 1766, May 6th, and read 1767, March 19th. It contains five problems, with dependent *scholia* and *corollaries*. In these he investigates the limits of attraction between the comets and the Sun, and the laws of motion and direction by which an elastic fluid or vapor arising from the head of a comet would be governed. He also deduces the masses and densities of comets from the observed breadth of the coma in the side next to the Sun. In this method, which he considers as entirely new to science, he infers that the density of the comet of 1665 was to the density of the Earth as 350 to 1; and that of the comet of 1682, as 5 to 11; and suggests an analogy in this respect, between comets and planets; that the densities are greater in proportion to their nearness to the Sun.

His explanation of the curved appearance of the tails of comets, which are occasionally manifested, contains this remark[17]—"that as no incurvature or deviation from the opposition to the Sun is perceived, but what may arise from the progressive motion of the head around the Sun, it appears probable that comets do not revolve on their axes."

In his second discourse before the college community April 18, 1759, he discussed the true theory of comets according to the work of Newton's "Principia," and also according to the laws formulated by Kepler, with the predictions of Halley. Like all his previous papers or lectures, Winthrop shows a profoundness of learning and authority. This is further evident from the mathematical computations connected with the solution of the orbital elements, and the origin of periodic comets, according to Halley.

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[15] Transactions, Royal Society, **12**, 405.

[16] Transactions, Royal Society, (old series), **57**, 132.

[17] "Lectures on Comets," p. XII, Professor Winthrop.

A more complete analysis of this colonial astronomer's knowledge of comets is not possible here, but further mention would be of interest and importance to the study of the history of astronomy in America.

As will be noted, Winthrop had no stated program by which to observe the "nightly heavens" regularly, as the modern astronomers have. He had no problems requiring long and continuous use of instruments and calculation for final solution. His was, essentially, the work of a pioneer laboring when time from his daily task would permit. Thus, again we find him in 1761 preparing, with foresight and diligence, plans to observe two events of great astronomical importance which took place in this country—the transits of *Venus,* in 1761 and 1769. Winthrop's keen sense of appreciation of the value of such opportunities was of vital significance in America's astronomical history. This is evident from the introduction to his first discourse[18] in 1769 on the use of the transit of *Venus.*

The first astronomical expedition in this country was that in which Harvard College and the Province of Massachusetts participated. That Harvard had a scholar so well trained, and disposed to undertake this scientific mission, speaks well for her eminence in science at that period. The ultimate success of this work depended upon the cooperation of many astronomers. European observatories, Greenwich and Paris, sent out five different observing parties to America. In Philadelphia, the American Philosophical Society authorized David Rittenhouse and a number of prominent gentlemen to make all preparation to observe this transit also.

A special act of the Massachusetts government granted the use of the Province sloop to convey Winthrop and two assistants, with instruments loaned by the College, to St. John's, Newfoundland. So, provided with a reflector having two wires, vertical and horizontal, and a clock, and all adjustments made, Winthrop says, "we waited for the critical hour, which proved favorable to our wishes." On June 6th the Sun rose at St. John's at 4^h 18^m with *Venus* upon its disk. He applied himself faithfully in observing the passage of the planet over the Sun, one assistant counting at the clock, the other recording the time and the observations made by Winthrop.

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[18] Two Lectures on the Parallax and Distance of the Sun as deducible from from the Transit of Venus, etc. March 1, 1769, Holden Chapel, Harvard College.

Without giving full details of the time of contacts and measurements of the passage of *Venus* across the Sun, it is sufficient to say that the results of the calculations gave the parallax of the Sun as 8".25. This value is apparently not the mean value of the parallax as it was derived from one set of observations based upon Halley's method; namely, the "method of duration," that is, observation of the contacts, and also of the position of the planet on the Sun. While Winthrop observed this transit very thoroly and made careful computations, yet his instruments and methods were naturally not such as to give results to be compared with those of Newcomb and others from the transits of 1878 and 1882. However, he later gathered all available observations, and from these determinations found the Sun's parallax, at its mean distance from the Earth, to be 8".68, which is comparable with the present accepted value. In the second transit of *Venus* (June 3, 1769), which again called forth important preparations both in Europe and the Colonies, similar observations were made by Winthrop in Cambridge, by West in Providence, and by Rittenhouse in Philadelphia.

The astronomer-royal, Dr. Maskelyne, had urged Winthrop to plan for observations in the Lake Superior region, where both the beginning and end were visible. But to his great disappointment, his health would not permit the long and rigorous journey. Consequently, Winthrop could only observe the first two contacts of this transit as the last two occurred at sunset (New England time). Again our colonial astronomer made a detailed study of all the observations available, both of this transit and of that of 1761; but the results exceeded the computed values of parallax given by him in his second lecture.

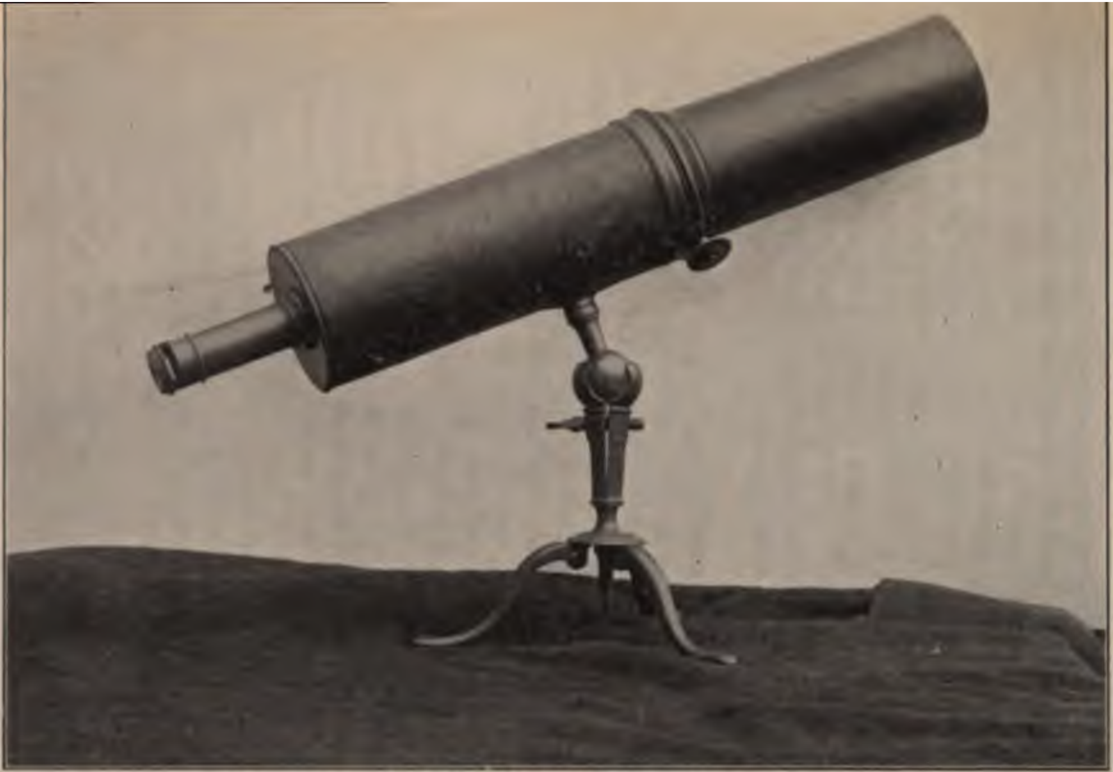
In order to obtain a clearer historical interpretation of this scholar's ideas and knowledge of the problems of astronomy, and those involved in transit observations, the following extracts of his first and second lectures upon the subject are given verbatim: "A transit of *Venus* over the Sun is the most uncommon and most important phenomenon that the whole compass of astronomy affords us. So uncommon is it, that it can never happen above twice in any century; in others but once; and in some centuries it cannot happen at all. And the importance of it is such as to supply us with a certain and complete solution of a very curious problem, which is inaccessible in any other way. On both accounts it well deserves a very particular attention."

"So extremely rare are these phenomena, and in fact till that which was observed in 1761, there never had been but one seen since the creation."

"This was in December of the year 1639, and it was seen by two persons only: Jeremiah Horrock, a young English astronomer of an admirable genius, who was the only person that predicted it, and a friend of his, William Crabtree. And when this of next June is passed the present race of mortals may take their leave of these transits, for there is not the least probability that anyone who sees this will see another."

"On account of their rarity alone they must afford an exquisite entertainment to an astronomical taste. But this is not all. There is another circumstance which strongly recommends them. They furnish the only adequate means of solving a most difficult problem,—that of determining the true distance of the Sun from the Earth. This has always been a principal object of astronomical inquiry. Without this we can never ascertain the true dimensions of the solar system and the several orbits of which it is composed, nor assign the magnitudes and densities of the Sun, the planets, and comets; nor of consequence attain a just idea of the grandeur of the works of God." . . .

"It will not be easy to give a distinct account of the several steps in the method of applying these phenomena to this purpose without the use of diagrams, which are not suitable to this place. I shall, notwithstanding, endeavor to convey to you as clear an idea as I can of the general methods, and in order to do it I shall trace things from their first principles."



WINTHROP'S TELESCOPE.

PRESERVED AT HARVARD COLLEGE OBSERVATORY.
Photographed by Mr. Leon Campbell with the permission of
Dr. E. C. Pickering, Director.

The remainder of the lecture is given up to a descriptive account of *Venus's* passage over the Sun and methods of observing, also the theory of parallax and geometrical demonstrations.

Winthrop early appreciated the function of exact time, and therefore during 1763 he communicated with Dr. Bliss, then astronomer-royal, regarding his observations of the transit of *Mercury* of 1743, with the express purpose of determining the longitude of Cambridge by comparing them with the European results[19]; and he gives it as his opinion that the longitude might thereby be determined with more exactness than by any observations that had been made use of for that purpose.

Solar eclipses were as rare celestial phenomena to Winthrop as to most others, but on the 5th of August, 1766, it is recorded[20] that he observed an eclipse of the Sun. He makes no reference to the nature of this eclipse; that is, whether it was partial, annular, or total. He gives only the time of beginning and ending. However, from other historical data, it does not seem to have been a total eclipse, for the first[21] recorded total eclipse of the Sun in America observed scientifically was that of June 16, 1806. Winthrop's object in observing this eclipse seems to have been to determine the difference of time between Greenwich and Cambridge, for the same eclipse was observed by Dr. Maskelyne, astronomer-royal, and a study was made of the differences shown by these observations.

That Winthrop attempted to make original discoveries in astronomy as early as his period, shows that he was something more than an observer working along set formulas and plans. We find that in the observation for the transit of *Venus* in 1761 he "viewed the Sun with great attention in the reflector, both on the 5th and 6th of June, in hopes to find a satellite of *Venus*[22], but in vain." There were several spots then on the Sun, but none that he saw could be a satellite.

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[19] See note, "Memoirs of the American Academy of Arts and Sciences, **1**, 57-8.

[20] "Memoirs American Academy of Arts and Sciences," **1**, 21.

[21] Grant, "History of Physical Astronomy," p. 367.

[22] *Philosophical Trans.*, abrid. ser., **12**, 157.

Like Rittenhouse, he also observed an apparent "duskishness" about the planet *Venus*[23] at the point of the first internal contact during a transit, but as the planet passed over the Sun he could not perceive it further.

Besides observing these principal phenomena, Winthrop occasionally observed the occultations of *Jupiter's* satellites, made frequent observations on the Sun's surface for spots, and also observed lunar eclipses, meteors and comets.

In 1769 Winthrop published an account in the Boston journals of the observations of the brilliant comet which appeared on September 1st. The remarkable feature of this comet was the length of its tail, which he measured to be 45 degrees.

Again in 1770, in June, a remarkable comet appeared and passed its perihelion point in August. This comet had no tail and was noted for its swiftness, for it described in one day an arc of more than 40 degrees. Winthrop ascribed this excessive motion to the fact of its approach to the Earth on that day to within one-fiftieth part of the Earth's distance from the Sun.[24] He observed this comet with care and the observations enabled him to calculate its orbital elements.

In conclusion it may be well to note that he made a number of observations on such miscellaneous phenomena as lightning, aberration of light and a study of variation of the magnetic needle. In the study of lightning he cooperated with Franklin regarding the electrical properties and the effect such properties have on "iron point," the term given to electrical conductors attached to buildings. He also defended Franklin's "iron points" against the attack and misunderstanding of the orthodox clergy, who asserted that they permitted electricity to come to the Earth to produce earthquakes.[25]

He displayed eloquence as a speaker, tact and dignity in arguing and defending scientific truth against the theologists of puritan New England, who were ever fearing theism would be overturned. His brilliant writings are an excellent type of colonial literature and should be preserved as a precious contribution to the foundation of the history of American science, and more particularly astronomy.

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[23] *Trans. Amer. Phil. Soc.*, 1, 25.

[24] Oliver, "Lecture on Comets," p. XVI.

[25] White, "A History of the Warfare of Science and Theology, 1, 366.

While it is true that neither Winthrop nor Rittenhouse established an observatory of any type, or laid a great foundation for an astronomical school, or made extraordinary discoveries and advances in celestial phenomena, yet what they did as pioneers with the highest possible motive, was to create a tradition which to this day has permeated pure science; namely, in giving to the philosophy of science an idealism which is so potent a factor of progress in our understanding of the laws of Nature.

The Royal Society elected him a Fellow in 1765, and the American Philosophical Society enrolled him as a member in 1768. From the University of Edinburgh in 1771 he received the honorary LL. D. degree; and his *alma mater* conferred upon him the same degree in 1773,—the first honorary degree of Doctor of Laws conferred by Harvard University.

Winthrop was honored as no man of his period had been. He was easily recognized as the most learned and capable of men, and this gave him power, influence and authority in the council with Washington, Adams and those who aided in the shaping of the future destiny of the new nation. His love of liberty and independence stamped him unquestionably as a loyal citizen of the new republic.

Winthrop was married twice, and one of his five sons, James, attained some degree of eminence as a scholar and scientist.

In Cambridge on the 3d of May, in 1779, at the age of 65 years, John Winthrop, scholar, scientist and astronomer, passed away in the fullness of his fame; and he lies buried with his ancestors in the old King's Chapel burying ground, Boston.

Stanford University, California.
May, 1916.

OUTLINE AND SUMMARY OF A STUDY OF MAGNITUDES IN THE GLOBULAR CLUSTER MESSIER 13.

By Harlow Shapley.

The measurement of the light intensity of a star as recorded by an ordinary photographic plate which is sensitive to blue light and by one especially prepared so as to be sensitive to yellow or mean visual light yields at once an indication of the star's color. In fact, this color-index, which is simply the difference between photographic and photovisual magnitude, not only defines the color of a star but gives also the spectral type as soon as due allowance is made for certain factors (size of the stars, for instance, and scattering of light in space) which may affect color without having a corresponding influence on the class of spectrum. For faint objects in crowded regions, such as the individual stars in stellar clusters, the color-index method is the best available for the determination of spectral type, and it gives at the same time values of the brightness in a standard magnitude system. Until recently, however, even this method could not be used for it necessarily depends upon accurate scales of magnitudes for the faint stars.

The importance of a special investigation of clusters lies in the fact that each globular system is a distinct stellar unit, and any light thrown on the structure or development of such groups must reflect on the structural characteristics of the local system of which the Sun is a member. One great advantage in studying stellar problems thru the agency of clusters is that their distances are so great that in statistical work all the stars of each one may be treated as at the same distance from the Earth. In other words, the distance factor is eliminated, and the measured apparent magnitudes differ only by a constant from absolute magnitudes. Consequently, in all correlations of brightness with other properties, such as distribution, color, and light variations, we are dealing directly with physical characteristics of the stars.

The derivation of magnitudes in globular clusters, previous to the work now in progress at Mount Wilson, has been based upon more or less uncertain standards and has made no pretense to accuracy. The studies of clusters, indeed, have chiefly been concerned with general descriptive work, the measurement of positions, the observation of variables, and theoretical discussions of laws of stellar distribution. The investigation at Mount Wilson aims mainly at the measurement of magnitudes and colors and the discussion of the problems arising in the course of the study.

The great globular cluster in *Hercules,* Messier 13, was placed first on the observing list. The spectra of a few of its stars had been photographed by Pease, and Barnard had observed conspicuous differences in color. Two catalogs of the positions of several hundred of the brightest objects have been made at Potsdam, and a number of investigations of the distribution of the stars are on record. For different parts of the work of forming a catalog of magnitudes twelve plates were secured at the principal focus of the 60-inch reflector, all but three of which contain exposures on the Polar Standards as well as on the cluster. The magnitude scales and zero points were thus transferred directly to the cluster from the North Pole. The tabulated magnitudes are based on four plates, the zero points are checked by four others, and additional photographs were used for the study of the variables and for determining the brightness of stars too faint to appear on the standard magnitude plates. By far the largest part of such work in globular clusters is in the identification and measurement of the stars. In deriving values for 1300 stars in Messier 13 more than ten thousand estimates and measures of magnitude were necessary. The detailed account will appear as No. 116 of the Contributions from the Mount Wilson Solar Observatory. The remainder of the present paper is devoted to a general summary of the investigation.

1. From an analysis of the residuals small systematic errors related to distance correction, astigmatism, and length of exposure are found, but none is important. The most serious difficulty involves the probable influence of the Eberhard effect in and near the center of the cluster. The relative error in the zero points of the two magnitude scales does not exceed a few hundredths of a magnitude, and no appreciable scale-divergence is found.

2. The probable error of an average color-index is about six hundredths of a magnitude. This does not entirely include the systematic error allied to the color excess in the center, but is valid for distance greater than 2′. From Table I, which summarizes a study of the errors, we find that for ninety-five per cent of the magnitudes used in the statistical discussions the average probable error is less than a twentieth of a magnitude.

TABLE I.

	PHOTOGRAPHIC		PHOTO-VISUAL	
	Whole Cluster	Distance > 2′	Whole Cluster	Distance > 2′
Probable error:				
One plate...........	±0^{m}.068	±0^{m}.057	±0^{m}.046	±0^{m}.044
Two plates..........	±0 .048	±0 .041	±0 .033	±0 .031
Corrected for systematic deviations:				
One plate...........	±0 .061	±0 .044	±0 .040	±0 .035
Two plates..........	±0 .043	±0 .031	±0 .029	±0 .025

3. A catalog of the photographic and photo-visual magnitudes of about 1300 stars has been prepared. Owing to the probable presence of systematic error in the magnitudes in the denser central regions, the lists published in Contribution No. 116 contain only about 650 stars; publication of the remainder awaits further investigation of suspected errors. Probably not more than 18 of the magnitudes refer to superposed non-cluster stars.

4. Discarding incomplete or doubtful results, 1049 magnitudes and color-indices are available for statistical investigation, of which 495 are outside the central region. The range of observed photo-visual magnitudes is from 11.9 to 16.8; but all of the stars are included only down to magnitude 15.5.

5. Five new variable stars have been discovered, making a total of seven in the cluster. The periods are probably short, and there is evidence that all are bluer at maximum than at minimum, suggesting the Cepheid type of variation. The two previously known variables are almost certainly Cepheids.

6. The values of the color-index in the cluster range from —0.52 to +1.96, with the greatest frequency about +0.90. Excluding the zone within 2′ of the center, the upper limit is +1.45, with greatest frequency near +0.70. More than

17 per cent of the values are negative (outside distance 2′), and there appears to be no reason for attributing this result to error of any kind. The frequency of the colors for the whole cluster and for the region more distant from the center than 2′ is shown in Table II. Color class may be taken as closely analogous to spectral class. Tabulated quantities are numbers of stars.

TABLE II.

	Color Class												
Region	b0 to b5	b5 to a0	a0 to a5	a5 to f0	f0 to f5	f5 to g0	g0 to g5	g5 to k0	k0 to k5	k5 to m0	m0 to m5	m5 to m9	All Colors
All of cluster..	22	91	83	71	99	223	243	114	45	33	15	5	1049
Distance >2′...	16	70	36	27	50	135	115	33	9	4	..	.	495

7. The size and distribution of the color-indices are what might be expected on the basis of no selective scattering of light in space. At least the absorption in the direction of the *Hercules* cluster must be less than +0.0001 mag. for each unit of distance ($\pi = 0''.1$). The values derived by Kapteyn, Jones, Van Rhyn, and some others are impossible in this case, even with the most favorable assumptions as to the distance of the cluster.

8. The average color index at greater distances from the center than 2′ is +0.55, corresponding to spectrum F4. Toward the center of the cluster it increases to at least +1.3, and no negative values appear. The increase is present for all magnitudes and is probably to be interpreted as a systematic photographic error, perhaps the Eberhard effect. If the phenomenon is real, however, it would indicate an absorption within the cluster, or a preferential concentration of red stars in that region.

9. The possible existence of "cluster absorption" suggests that for lower galactic latitudes there may be a measurable amount of space absorption: observations are being made for the purpose of testing this hypothesis.

10. The determination by Pease of spectra of individual stars in the cluster gives results confirmatory of the direct interpretation of color class as spectral type, and verifies the excess of color in the center.

11. Of the four hundred faintest stars measured in the cluster, 85 per cent are bluer than the color class g0, which

corresponds to solar spectral type; of the four hundred brightest stars 75 per cent are redder than g0. An analogous result holds for the outer regions alone. The average magnitude for each color class in the whole cluster and in the region outside 2′ is shown in Table III.

TABLE III.

	Color Glass							Average
							All	Color
Region	b	a	f	g	k	m	Colors	Class
All of cluster..	15.19	14.99	14.78	14.15	13.34	12.96	14.50	f6
Distance >2′...	15.20	15.01	14.85	14.28	12.74	.....	14.71	f3

12. The almost linear decrease of color-index with decreasing brightness is in evidence in all regions of the cluster. The phenomenon probably has an important significance in considerations of the order of development of giant stars.

13. Between photo-visual magnitudes 16.0 and 16.8 only four out of the special list of a hundred faint stars have color-indices greater than half a magnitude, and none is found redder than the Sun.

14. There is some evidence that the brighter stars are more strongly condensed in the center of the cluster than the faint ones; at least the average magnitude is brighter, even without allowing for the color excess. Outside the central zone the cluster stars seem to be very thoroly mixed with respect to magnitude and color.

15. The laws connecting star-density and distance cannot be determined until the phenomenon interpreted here as the Eberhard effect (which also depends on distance from the center) has been thoroly investigated; even neglecting this effect, the distribution laws ordinarily derived must be recognized as applying to only that very small percentage of all the stars which is represented by those of exceptionally high intrinsic brightness.

16. The probable distance of the *Hercules* cluster is estimated from considerations of its variable stars, its fragmentary luminosity curves, and the average apparent brightness of certain color groups. The parallax must be less than $+0''.0001$ and is probably greater than $+0''.00001$.

17. At the provisionally adopted distance of a hundred thousand light-years, the cluster would be more than a thousand light-years in diameter.

18. There seems to be reasonably clear evidence that this and similar globular clusters are very distant systems, distinct from our galaxy and perhaps not greatly inferior to it in size. The open clusters, on the other hand, seem to be relatively small parts of the local system; but further observation is necessary to make certain of this deduction.

In conclusion it may be stated that since the completion of the work on Messier 13 similar but less extensive studies have been made of six other globular clusters and of two open groups. The results from the globular clusters, so far as they have been analyzed, are in good agreement with those summarized above for Messier 13. The presence of blue stars and the absence of exceptionally large color-indices indicate that the effectiveness of interstellar media as light scattering agents is very slight. In particular, the phenomenon of decreasing color-index with decreasing brightness holds for such clusters as Messier 3, 5, and 15, and is very probably a general characteristic of all globular systems.
August 1916.

A LUMINOUS OBJECT SEEN ON MAY 4, 1916.

By C. D. Perrine.

About 9^h 10^m in the evening of May 4th (Córdoba mean time) Dr. Glancy called my attention to a peculiar object in the southeastern sky.

It was then a bright streak just below α *Pavonis*, sensibly straight, about 8° or 10° long and one-half to one degree in width. It was more sharply defined toward the west, that extremity resembling the head of a large bright comet, but without any well defined condensation or nucleus. In general appearance to the naked eye and with the exception of a changed position it was an exact counterpart on a smaller scale of Halley's comet when this object was near to the Earth and its head near enough to the horizon to suffer greatly by absorption from the atmosphere.

After a few minutes' examination with field glasses a series of pointings was made as long as it could be seen with the finder of the 12-inch equatorial. These pointings were upon the western end of the object with respect to terrestrial objects, or the eastern end with respect to the stars.

These observations are as follows:

Córdoba Mean Time	R. A.	Decl.	Remarks
$8^h\ 52^m$	$20^h\ 18^m.5$	—57°	Casually observed and set down from memory.
9 34	21 02 .3	—55 .8	3 pointings.
9 46	21 21 .2	—55 .5	2 pointings.
9 58	21 27	—55 ¼	1 pointing, very uncertain.

The first observation was made by Dr. Glancy; the last three by Dr. Perrine.

When first seen (estimated to be at $8^h\ 52^m \pm 2^m$) by Dr. Glancy, the western extremity of the object was in apparent coincidence with the 2d magnitude star α *Pavonis*. It was soon seen that it was approaching the horizon and would shortly be lost to view—the diurnal motion not sufficiently counteracting its own motion.

In the intervals between pointings it was studied with field-glasses and with the naked eye. It grew fainter as it approached the horizon. After it had disappeared a low-lying bank of haze or cloud was observed at that point. During the earlier stages of its apparition there seemed few or no signs of streamers which are often observable in the tails of comets. At about the middle of its period of visibility when it had grown perceptibly fainter the portion midway looked, with field-glasses, like the main streamer of the middle portion of a comet's tail. It retained its rectilinear form as long as it could be seen.

There were no clouds, with the possible exception mentioned above, in any part of the sky at any time during the apparition of this object nor at any time during the night in question so far as I know. The sky was of its usual transparency and work was in progress with the astrographic telescope (on chart plates) and with the meridian circle as well as earlier with the 12-inch equatorial with which Dr. Glancy observed Neujmin's comet.

The appearance of the object was not that of an ordinary aqueous cloud. I think there can be no doubt that it was a self-luminous object.

There were no means of photographing it or of examining its spectrum in the short time available.

Upon plotting the observed pointings including the estimated position by Dr. Glancy at 8^h 52^m it is found that they all appear to fall upon a great circle passing thru the Sun within their probable errors. The observed motion was 10° on a great circle toward the Sun in the interval of one hour.

Explanations of the nature of this object seem to be limited by the circumstances to two:—*a,* that it was a comet traveling very close to the Earth and toward the Sun or *b,* that it was the cloud left by a meteor.

The appearance is better explained by the assumption that it was a comet. There were no changes of form such as usually occur in meteor clouds—the object was sensibly straight and streamer-like thruout its entire apparition. The extremity nearest the Sun's place was as sharply defined as, and similar in shape to, the head of a large comet close to the Earth, while the opposite portion faded out gradually like the tail of a comet. There was no pronounced condensation and so far as I could determine no nucleus altho one stellar object of approximately sixth magnitude was suspected to have motion. It was not possible under the circumstances, however, to verify the fact. The axis of the object was at first nearly parallel to the horizon, but later became more inclined, the west (terrestrial) end being nearest the horizon.

The tremendous geocentric motion demanded, while not impossible, would be, nevertheless, very unusual.

Some time after the apparition of this object several meteors were noticed, one at least of which was visible in the southeastern sky, coming from a radiant to the north and perhaps 30° or 40° above the horizon.

The observed motion extrapolated would have carried the object almost to the Sun's place at sunrise. There seemed a possibility, however, that it might slow up and that it would be visible before sunrise. It was therefore, carefully looked for, in a good sky, but nothing seen of it.

Considering all the circumstances, particularly that its motion would carry it rapidly into the northern sky if it were a comet, it was deemed best to warn northern observers. Hence the following telegram was sent to Harvard College Observatory:

May 5, 1916.

Bright object visible here last night nine to ten. Moved from *alpha Pavonis* ten degrees toward Sun's place. Tail. Possibly a comet.

It is not considered, however, that its nature can be established without observations from other points. Requests for observations were sent to the newspapers but no reports have been received.

Dr. Glancy has investigated the question of an orbit for the positions, which is also interesting from a theoretical standpoint on account of the possibility of such a close approach, and her results follow.

Observatorio Nacional Argentino,
Córdoba, June 16, 1916.

A LUMINOUS OBJECT SUSPECTED TO BE A COMET.

By A. Estelle Glancy.

On the evening of May 4th an object resembling a comet with a long straight tail was seen at Córdoba in the southeast near α *Pavonis*, (see the preceding note by Dr. Perrine). The tail pointed away from the Sun; the motion was directed toward the Sun. Three observations within an interval of an hour showed a motion of 10° on a great circle. Theoretically such an arc might be made to yield some sort of an orbit, and it is interesting to study what can be derived mathematically.

Following are the three observations, by Dr. Perrine and the writer, the middle one unfortunately close to the third, and the first one a casual naked-eye note of the position.

Gr. M. T.	R. A.	Decl.
May 4.548	20h 18m.5	−57°.0
May 4.577	21 02 .3	−55 .8
May 4.585	21 21 2	−55 .5

(Uncorrected for parallax.)

The calculations presented certain difficulties, but finally the following set of elements was adopted:

$$T = 1916 \text{ June } 14$$
$$i = 103^\circ$$
$$\Omega = 224^\circ$$
$$\omega = 95^\circ$$
$$\log e = 9.967$$
$$\log a = 0.809$$

This orbit satisfies the middle observation (corrected for parallax), and leaves outstanding the following residuals for the first and third places, (corrected for parallax).

	(O—C) (1)	(3)
$\cos \delta \, \Delta \alpha$	$-0.^\circ04$	$+0^\circ.13$
$\Delta \delta$	$-0\ .49$	$-0\ .29$

A short ephemeris is added.

Gr. M. T.	R. A.	Decl.	$\log \rho$
May 4.577 (middle obs.)	315°	— 57°	7.35
.627	1	— 40	6.99
.677	55	30	7.10
.727	74	47	7.42
.777	82	49	7.62

Too much confidence should not be placed in such an orbit as this, but, whatever its reliability, it has a threefold interest. If the object was a real comet where should it have been searched for on the following morning? Granting a real comet to have been observed at the three given times only, what kind of an orbit could be calculated, if any? And how do the methods of computing orbits hold when a comet and the Earth make a close approach?

The observed motion was such that we were led to predict a possible visibility of the object in the eastern sky on the following morning, and a search was accordingly made. Nothing was seen. If the ephemeris is reliable, our failure to find the object is satisfactorily explained. It could only have been seen in more northern latitudes and in the evening sky.

Altho such an unfavorable case, an orbit satisfying the three given observations has been set up, and it is quite ordinary in its characteristics. In fact, in a rough way, it resembles Comet 1903*c*.

That the calculations would present difficulties was to be expected. It was only by the combined use of the equations given by Oppolzer and those in Leuschner's Short Method that any kind of an orbit was derived. Without stating the difficulties, it is sufficient to note the unequal intervals, the small value of the geocentric distance, (at the time of the middle observation the geocentric distance was 0.0022 of an astronomical unit), the correspondingly large parallax, and the relative attraction of the Earth, and the short heliocentric arc described by a comet at unit distance from the Sun during an interval of an hour. The attraction of the Earth has been neglected, owing to the anticipated difficulties in its consideration and the hope that the two body problem would be adequate to disprove or confirm the predicted place for the following morning.

Even if only a hypothetical case, here is an example of what may happen at the time of a close approach of comet and Earth: A comet might traverse an arc of 180° in the course of a night, and if it should be an unexpected comet, it would be completely lost if such a short arc orbit has no value.

Considered as a comet, all the evidence is favorable. It was moving toward the Sun. The shape of the tail was fairly permanent. The position angle of the tail projected on to the orbit plane places the tail at an angle of 57° with the radius vector, the tail preceding the radius vector, a deviation which has precedents in previous comets. The elements are entirely reasonable, and the ephemeris explains the failure to find the object on the following morning.

On the other hand, deducting the motion of the Earth, we should have for the motion of a body within the Earth's atmosphere

2° east 1°.5 north

The interpretation of the phenomenon as a quiescent meteor cloud is plausible. Several years ago, in Argentina, there was seen a meteor cloud of this general type, long and narrow and of several hours' duration. The greatest objection to this hypothesis is the permanence of shape. Under the influence of shifting air currents, the cloud should become zigzag, but this difficulty is removed on the assumption of a high altitude where the air currents are known to be more steady. One more objection might be named: the absence of reports from the numerous meteorological stations scattered about the country.

Only additional observations could establish the character of the object and it must probably remain an open question. But the case has considerable interest in view of its uniqueness, and the numerical results are presented for what they are worth.

Observatorio Nacional,
Córdoba, Argentina,
June 16, 1916.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1916.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter.	Sept. 4th,	$8^h 26^m$ P.M.	First Quarter.	Oct. 4th,	3^h 0^m A.M.
Full Moon...	" 11th,	12 31 P.M.	Full Moon...	" 10th,	11 1 P.M.
Last Quarter.	" 18th,	9 35 P.M.	Last Quarter.	" 18th,	5 9 P.M.
New Moon...	" 26th,	11 34 P.M.	New Moon...	" 26th,	12 37 P.M.

The Moon will again pass over the *Pleiades* group and a number of the more prominent stars will be occulted in the early morning of October 14th before sunrise. As the Moon is then in the third quarter the immersions will take place on the bright limb. There will be an unusual number of occultations of planets during September and October, but none of these will be observable in the United States. The Moon will pass over *Saturn* and *Neptune* on the night of September 21-22d, and over *Venus* on the morning of September 24th. *Saturn* and *Neptune* will again be occulted on October 19th.

The autumnal equinox, when the Sun crosses the equator from north to south, occurs September 23rd, 1^h 14^m A. M. Pacific time.

Mercury is an evening star on September 1, setting a little less than an hour after sunset. It is then a little too near the Sun for naked eye visibility. It reaches greatest east elongation on September 9th. The elongation, 26° 54′, is a large one as it comes only about a week after aphelion, but the planet is so far south of the Sun that it will set scarcely an hour after sunset and conditions are not favorable for naked eye view. The planet passes inferior conjunction on the morning of October 5th and becomes a morning star. Greatest west elongation occurs on October 20th. This elongation, 18° 17′, is much under the average as perihelion passage came on October 16th, but the planet is several degrees north of the Sun, and by the middle of the month the planet will rise about an hour and one-half before sunrise. This interval diminishes somewhat toward the close of the month but remains well over an hour. For the last three weeks of the month, therefore, *Mercury* will be an easy object in the morning twilight.

Venus is in fine position for morning observation, rising about three and one-half hours before sunrise thruout the two months' period. It reaches its greatest west elongation, 46° 1′, on September 12th, and from that date the apparent distance between Sun and planet begins to decrease. The amount of this diminution up to October 31st is about 9°; but the relative motion of *Venus* and the Sun carries the planet considerably to the north of the Sun, and the total effect on the difference of time in the rising of the planet and of the Sun is only about ten minutes. During the two months the planet moves 64° eastward and 15° southward from *Cancer* thru *Leo* to the western boundary of *Virgo*. On October 7th it passes about half a degree south of *Regulus*, *α Leonis*. While the planet is not quite as bright as it was at the time of greatest brilliancy in August, it will still retain nearly half its light up to the end of October, and will be by far the most conspicuous object in the sky.

Mars is still in the evening sky, but is drawing closer to the Sun and has ceased to be conspicuous. On September 1st it sets about two hours, and on October 31st not quite an hour and one-half after sunset. It is nearing its maximum distance from the Earth and is nearly at its least brightness. However, it is still a little brighter than the pole star and can be seen in the evening twilight without much difficulty. During the two months it moves 42° eastward and 13° southward from a position in *Virgo* about 3° east of *Spica*, the principal star of the constellation, thru *Libra* and into *Scorpio,* to a place 1° west and 4° north of *Antares,* α *Scorpii.* On September 29th it passes less than 1° south of α *Librae,* a third magnitude star.

Jupiter is getting into good position for evening observation. On September 1st it rises before 9 P. M. and on October 31st shortly before sunset. It reaches opposition with the Sun on October 23rd and is then above the horizon thruout the entire night. Its motion during September and October is retrograde, about 6° eastward and 2° southward in the constellation *Aries.* No bright star is near it.

Saturn rises before 2 A. M. on September 1st and shortly after 10 P. M. on October 31st. On September 1st it is nearly on the prolongation of the line from *Castor* to *Pollux* and distant from the latter an amount about 50% greater than the distance between the stars. Its motion during the two months is about 4° eastward into the constellation *Cancer.* On the night of September 5th it is in conjunction with *Venus,* the latter passing about 3° to the south. As seen in the telescope the rings appear less widely open than they were early in the year, the minor axis of the ring being perceptibly less than the polar diameter of the planet.

Uranus sets on September 1st at about half past three A. M. and at half an hour before midnight on October 31st. It is nearly stationary in the constellation *Capricorn,* moving about 1° westward until October 20th. It then begins to move slowly eastward. On September 1st the nearest moderately bright star is ι *Capricorni,* a small fourth magnitude, a little less than 1° south of the planet. At the end of October the planet is about 1° west and 24′ north of the star. The planet is not bright, not much above naked eye visibility on a clear moonless night.

Neptune is in the constellation *Cancer* somewhat east of *Saturn.* On September 13th it is in conjunction with *Venus,* the latter passing about 2° to the south.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1916.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter.	Nov.	2d.	9^h	51^m	A.M.	First Quarter.	Dec.	1st,	5^h	55^m	P.M.
Full Moon...	"	9th,	12	18	P.M.	Full Moon...	"	9th,	4	44	A.M.
Last Quarter.	"	17th,	2	0	P.M.	Last Quarter.	"	17th,	10	6	A.M.
New Moon...	"	25th,	12	50	A.M.	New Moon...	"	24th,	12	31	P.M.
						First Quarter.	"	31st,	4	7	A.M.

The fifth and last eclipse of the year, *a Partial Eclipse of the Sun*, will occur December 24. The maximum obscuration of the Sun will be only one hundredth of its diameter, and it will be visible only in the regions far south of Africa.

The Moon will again occult the *Pleiades* group on December 7th, but nearly all of the occultations will take place before moonrise in the United States.

The Sun reaches the winter solstice and begins to move northward on December 21st, 7^h 59^m Pacific time.

Mercury is a morning star on November 1st, and rises a little more than an hour before sunrise, in fair position for observation. It gradually approaches the Sun, passing superior conjunction and becoming an evening star on the night of November 23d. It gradually increases its distance from the Sun, and shortly after the middle of December it attains a sufficient distance for visibility in the evening twilight. At the end of the month it remains above the horizon nearly an hour and one-half, and is then an easy naked eye object. It will reach greatest east elongation in January.

Venus is still in the morning sky but is gradually drawing nearer to the Sun. On November 1st it rises about three and one-half hours before sunrise and this interval diminishes to a little more than two hours by the end of December. It will also diminish perceptibly in brightness due to its increased distance from the Earth. It will, during the two months, move 71° eastward and 23° southward among the stars from the western part of *Virgo* thru *Libra* into *Scorpio*. On November 20th it passes about 4° north of the first magnitude star *Spica*, and on December 28th it is about 5°

north of the first magnitude star *Antares.* It passes its perihelion on November 11th, but the orbit is so nearly circular that this makes very little difference in appearance or apparent motion. This is very different from the conditions in the case of *Mercury* and *Mars,* whose orbits are relatively very eccentric. In these latter the situation of the planet with reference to perihelion or aphelion causes a variation of quite a number of days in time of conjunction or greatest elongation.

Mars is gradually approaching the Sun and by the end of December sets just about one hour after sunset. On November 1st the interval is about an hour and one-half. As the planet is now nearly at its faintest, about as bright as the pole star, it will not be a very easy object for naked eye view at any time during the two months' period, but it can be seen, under good weather conditions at any rate, during November. Its motion among the stars is about 50° almost due eastward, from a position in *Scorpio,* about 4° north ot the first magnitude star *Antares* thru *Sagittarius* to the western border of *Capricornus.* During the first half of December it moves eastward a short distance north of the "Milk Dipper" group in *Sagittarius.* Its actual distance from the Earth is still increasing slowly and will continue to do so until some time toward the end of February, about the time of conjunction with the Sun. It will reach its perihelion at almost the same time. *Mercury* and *Mars* are in conjunction on December 22nd, but both are too near the Sun for easy naked eye observation on that date.

Jupiter passed opposition with the Sun on October 23d, and consequently will be above the horizon nearly all night in November. It will set earlier each night by about four minutes, so that at the end of December it will set at about half after 1 A. M. It is in the eastern part of *Pisces* and its motion up to December 21st is about 3° westward and 1° southward. During the rest of the month it moves very slowly eastward. When at its extreme westward position on December 21st it is in almost exactly the same place among the stars which it held on June 1st, being only 10′ south. On account of its considerable distance there is comparatively little change in its apparent brightness due to the relative positions of planet, Sun, and Earth, less than one magnitude between brightness at conjunction and at opposition.

Saturn is getting into better position for evening observation. On November 1st it rises at 10:20 P. M., and at about six in the evening at the end of December. It is in *Cancer* and moves eastward up to November 12th. During the rest of the period it moves about 2° westward. The apparent minor axis of the rings is very slightly larger than it was during the last period, but is distinctly smaller than the polar axis of the planet.

Uranus sets shortly before midnight on November 1st and before 8 P. M. on December 31st, but is still in fair position for evening observation. It remains in the constellation *Capricornus*, moving 1° 42′ eastward and 34′ northward during the month. On November 1st it is a little less than 1° west and 0°.5 north of the small fourth magnitude ι *Capricorni*. On December 12th it passes 0°.7 north of the star, a distance about one-third greater than the apparent diameter of the Moon.

Neptune is in *Cancer* east of the position of *Saturn*.

THE SAN DIEGO MEETING OF THE PACIFIC DIVISION OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, AND OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC.

The first meeting of the Pacific Division of the American Association for the Advancement of Science was held in San Diego, August 9 to 12, 1916, and was a success from every point of view. The officers and committees of the Pacific Division and of those of the affiliated societies which held meetings in conjunction with that of the Pacific Division planned the programs carefully, and the local committee on arrangements made every possible provision for the comfort and entertainment of the visiting members. The local committee was generously assisted in its work by the San Diego Chamber of Commerce, the Woman's Board of the Panama-California International Exposition, the staff at the Scripp's

Institution for Biological Research at La Jolla, the U. S. Bureau of Fisheries thru the officers and scientific staff of the *Albatross,* and by a number of firms engaged in commercial work of scientific interest; e. g., the kelp-reduction plants, the salt works and the tuna canneries.

The dedication exercises of the Scripp's Institution for Biological Research, La Jolla, were held on the afternoon of the opening day of the meeting, Wednesday, August 9. President B. I. Wheeler presided, and, after the invocation pronounced by the Bishop of Los Angeles, Rt. Rev. Joseph H. Johnson, addresses were made by Dr. David Starr Jordan, Dr. D. T. MacDougal, Professor G. H. Parker, and Professor Wm. E. Ritter, the scientific director of the institution.

Headquarters for the Pacific Division had been established in the lobby of the U. S. Grant Hotel and the general sessions of the Division were held in the assembly hall of the hotel on the evenings of Wednesday, Thursday, and Friday, August 9, 10, and 11. In opening the first meeting, on Wednesday evening, Dr. W. W. Campbell, president of the Pacific Division, called attention to the fact that this was the initial meeting of the Division and briefly outlined the history of the movement that led to its formation. He then introduced Hon. Lyman J. Gage, who welcomed the members of the Pacific Division and of the participating societies to San Diego. Dr. D. T. MacDougal, chairman of the executive committee of the Division, responded, and the address of the evening was then given by Dr. Campbell on the subject "What We Know About Comets." This address, which was fully illustrated by lantern slides, will soon be published, and no attempt will be made to give an abstract of it here. A very pleasant informal reception concluded the evening's program.

At the general session on Thursday evening the speaker was Dr. Barton W. Evermann, Director of the Museum, California Academy of Sciences, San Francisco, who chose for his subject, "Modern Natural History Museums and Their Relation to Public Education."

At the third general session, on Friday evening, Dr. Frank F. Wesbrook, president of the University of British Columbia, Vancouver, spoke on "The Physician of Tomorrow."

Good audiences were present on all three evenings—indeed, the attendance at all of the meetings—the separate scientific meetings as well as the general sessions was encouragingly large.

On Thursday evening a brief business meeting was held at which the present executive committee was re-elected, and it was voted that the choice of the next president and of the time and place of the next meeting be left to this committee.

The scientific sessions of the participating societies were held in various rooms of the San Diego High School building in the forenoons and afternoons of Thursday and Friday. Saturday was devoted to excursions to points of interest in the neighborhood of the city and at 7 o'clock of that evening the members of the Division gathered in the dining room of the U. S. Grant Hotel for the final function of the session—the Association dinner. Dr. E. L. Hardy, principal of the San Diego Normal School, acted as toastmaster, and appropriate addresses were made by Drs. F. R. Burnham and Fred Baker of San Diego, and by Messrs. W. W. Campbell, J. C. Merriam and F. F. Wesbrook.

In the absence of the president and other officers of the society, the meeting of the Astronomical Society of the Pacific on Thursday morning, August 10, was opened by the chairman of the program committee, Dr. R. G. Aitken. At his request Dr. W. S. Adams of the Solar Observatory, Mount Wilson, presided at the morning session, which was entirely devoted to a symposium on the nebulæ. The animated discussion of all the papers presented at this and at the later sessions proved their interest to the members present, and formed a most profitable feature of the meetings.

At the afternoon session, Dr. W. W. Campbell, of the Lick Observatory, was called to the chair. The papers at this session related principally to spectroscopic investigations. The remaining papers were presented at the session held on Friday forenoon, over which Professor Charles Burckhalter of the Chabot Observatory was called to preside. The closing remarks of the meeting were made by Dr. Campbell.

On the following pages brief abstracts are given of all of the papers, in the order in which they were read, except of those which appear in full on other pages of this number. For these, titles and references are given.

FORMS OF PLANETARY NEBULÆ: *Heber D. Curtis.*

The forms of fifty planetary nebulæ have been studied with the Crossley Reflector, using varying lengths of exposure times in order to get the structural detail of the very bright central portions as well as the fainter outlying parts of the planetary nebulæ. The majority of the planetaries show a more or less regular ring or shell structure, generally with a central star. Lantern slides were exhibited showing the various types observed.

SPECTROGRAPHIC OBSERVATIONS OF RELATIVE MOTIONS WITHIN THE PLANETARY NEBULÆ:

W. W. Campbell and *J. H. Moore.*

In the past nine months, as opportunity offered, the D. O. Mills three-prism spectrograph and the 36-inch Lick telescope in combination have searched for rotation effects in thirty-three planetary nebulæ. Definite evidence of rotation has been observed in sixteen nebulæ and suspected in five others. For twelve nebulæ no evidence of rotation was obtained, possibly because the axis of rotation in some of these may be pointing approximately toward the earth, in which case the spectroscopic method would not be applicable.

In the nebulæ which are more and more condensed as the center is approached, we seem to be dealing with simple cases of rotating bodies, with the outer strata rotating more slowly than the strata nearer the center. In other nebulæ showing ring structure with central nuclei, rotation effects seem to be combined with other forms of motion.

The central sections of the bright lines in the spectra of several nebulæ are bowed toward the red and widened. The interpretation which suggests itself is that the nebular materials serving as the source of light—presumably those in the hemisphere nearest the observer—are moving in toward the nebular nucleus. This hypothesis at least calls for careful consideration.

The results give valuable evidence as to the probable masses of the planetary nebulæ. They seem to contain sufficient material to form systems more extensive than our solar system.

The paper is illustrated with lantern slides of a few of the nebulæ and their spectra.

THE ROTATION AND RADIAL VELOCITY OF THE SPIRAL NEBULA N. G. C. 4594: *Francis G. Pease.*

A spectrum photograph of this nebula of 80 hours exposure with the 60-inch reflector is approximately of type F5. The slit was set along the major axis of the greatly elongated ellipse which marks the boundary of the nebula—the object is nearly edge-on to the observer. Light was thus received from points at different distances from the nucleus. An extraordinary feature is that the relation between radial velocity and distance is sensibly linear, thus:

$$\text{Velocity} = -2.78\,x + 1180$$

in which x is the distance from the center in seconds of arc.

The radial velocity of the system is accordingly 1180 km/sec., while the rotation velocity at a distance of $2'$ is 330 km/sec. Assuming the rotational component to be the same as that derived by van Maanen for Messier 101, the parallax is found to be of the order of $0''.0001$.

COLOR PHOTOGRAPHS OF NEBULÆ: *Frederick H. Seares.*

Slides are shown illustrating the distribution of color in several of the spiral nebulæ. Photographs on ordinary plates compared with others on isochromatic plates exposed behind a yellow filter show that the nuclei are yellow or reddish, while the branches, and especially the condensations scattered along them, are intensely blue and possess a photographic activity similar to that of the central star in the Ring Nebula. The planetary N. G. C. 3242, on the other hand, shows no important differences in the intensity distribution of its blue and yellow light.

SPECTROGRAPHIC OBSERVATIONS OF NEBULÆ AND STAR CLUSTERS: *V. M. Slipher.*

The continuation of the spectrographic observations of nebulæ and clusters reported upon in 1914, at Evanston, has not—by the inclusion of additional objects—much changed the average radial velocity of 400 km/sec. for the spiral nebulæ. Other spirals have been found to show rotational displacements and several spectrograms of the Great Andromeda Nebula fully confirm the earlier indications of the rotation of this nebula. Some interesting types of nebular spectra have been met with, the most remarkable case being that of the Crab Nebula in *Taurus* in which the chief nebular bright lines seem to be split into two components suggesting the Stark electric field analysis for hydrogen, helium and lithium.

The radial velocity of the globular clusters is less than that of the spiral nebulæ and their spectra are blends of early and later type stars with the relative intensities of the types varying from cluster to cluster.

ON THE MOTION OF NEBULOUS FILAMENTS IN N. G. C. 6992:

C. O. Lampland.

The intricate structure and definite character of some of the filaments in the nebula N. G. C. 6992 should make it possible to detect comparatively small changes that may take place. Two photographs of this object, separated by an interval of about fourteen years, were examined with a Zeiss comparator equipped with a Blink-Mikroskop. The earlier photograph was a copy on glass of Professor Ritchey's fine photograph of this nebula and the one of later date was from a negative made with the 40-inch reflector of the Lowell Observatory. In the south part of the nebulosity there are apparently slight displacements of small portions of some of the filaments.

VARIABLE STARS IN THE LAGOON NEBULA, N. G. C. 6523:

C. O. Lampland.

Four negatives of the Lagoon Nebula, made with the 40-inch reflector in July, 1915, have been examined with the Zeiss comparator and twelve variables have been found in different parts of the nebulosity. Most of these stars are faint, in the neighborhood of the sixteenth and seventeenth magnitude, and as a rule the variation in brightness is small, roughly a magnitude, except for three of the stars where variations from two to three magnitudes are shown.

A SIMPLE METHOD FOR DETERMINING THE COLOR OF A STAR: *Frederick H. Seares.*

With suitable precautions the ratio of the exposure times necessary for the blue and yellow light of a star to produce photographic images of the same size is a reliable measure of the star's color. The precision is sufficient for even a single photograph to show the greater redness of stars of high luminosity, spectral type remaining the same.

NOTES ON STELLAR CLUSTERS: *Harlow Shapley.*

The investigation of magnitudes in clusters, reported on for Messier 13 a year ago, has been extended to six additional globular systems. For Messier 3, 5, and 15 a study of the relation between color index and magnitude shows that the brighter stars in all of these clusters are redder than those of the 15th and 16th magnitude, a result confirming that obtained for Messier 13. Preliminary results for Messier 4, 9, and 14 also agree in showing the decrease of color with brightness. The absence of light-scattering material in space is verified by the new data. In Messier 9 some new variable stars have been found. The variables in Messier 3 are found to be similar in color to the isolated cluster-type variables, which they resemble in range and other peculiarities of light variation.

A RELATION BETWEEN THE CONVERGENCE WAVE-LENGTHS IN SPECTRAL SERIES AND THE RADII OF THEIR RESPECTIVE ATOMS AS COMPUTED FROM EINSTEIN'S PHOTO-ELECTRIC EQUATION AND BY OTHER METHODS: *Fernando Sanford.*

It seems to be very definitely established that electrons discharged from metals under the stimulus of ultra-violet light have, after leaving the metal, velocities such that their kinetic energies are given by Einstein's equation, $\frac{1}{2}mv^2 = h\nu - p$, where h = Planck's constant, ν = the vibration frequency of the incident light and p = the work required to remove an electron from the metal. Before leaving the metal the energy of a discharged electron must accordingly have been $\frac{1}{2}mv^2 = h\nu$.

If this energy be regarded as the energy of revolution of the electron about its electropositive sub-atom with the frequency of the incident light, it can be shown that the period of rotation would be proportional to the square of the orbital radius, and, hence, if this electron were itself a source of radiation, the wave-length of its radiation would be proportional to the square of its orbital radius.

$$\text{Thus } \tfrac{1}{2}mv^2 = h\nu. \quad \text{Hence } v^2 = \frac{2h\nu}{m}.$$

$$\nu = \frac{3 \times 10^{10}}{\lambda}.$$

$$h = 6.57 \times 10^{-27}$$

$$m = 10^{-27}$$

$$\frac{h}{m} = 6.57$$

$$v^2 = \frac{6.57 \times 6 \times 10^{10}}{\lambda} = \frac{39.4 \times 10^{10}}{\lambda}$$

$$\text{Also } v = 2\pi R\nu = 6.28 \times \frac{3 \times 10^{10}}{\lambda} \times R,$$

$$\text{and } v^2 = \frac{355.3 \times 10^{20} \times R^2}{\lambda^2}$$

Equating these two values of v^2 and dividing by λ, we have

$$\frac{R^2}{\lambda} = 1.1 \times 10^{-11}.$$

The above assumption of electrons revolving in elliptical or circular orbits would necessitate the assumption of a different electronic radius for each line of the spectrum, and would not enable us to say anything definite about *an* atomic radius. However, since many of the elements have spectral series which seem to converge toward a shortest possible wave-length for that particular system, we may calculate the shortest possible electronic radius for each spectral series. The fact that no electron can revolve about the positive nucleus of this particular system closer than the electron which would give the convergence wave-length seems to justify the assumption that the convergence radius represents the true radius of the central electropositive atom. If this assumption be correct, the convergence wave-lengths of corresponding series in similar elements should be proportional to the square of the respective atomic radii.

Unfortunately, atomic radii can be determined only approximately. Heydweiller has calculated atomic radii for a considerable number of atoms from the refraction constants of their ions in dilute water solutions, using the Lorenz-Lorentz formula and adopting the assumption made by the authors of this formula that the ratio $\frac{n^2 - 1}{n^2 + 2}$ represents the ratio of the real to the apparent atomic volume. Numbers which are generally regarded as proportional to the atomic radii may also be obtained by taking the cube roots of the atomic volume in the liquid or solid state.

It is shown in the paper that the atomic radii computed from Einstein's equation are approximately twice the atomic radii as computed by Heydweiller, and that for a number of groups of similar elements the atomic radii computed from the convergence wave-lengths are closely proportional to both Heydweiller's radii and the cube roots of the atomic volume. It is also shown that in the Ritz formula,

$$\nu = A - \frac{N_0}{\left(n + a + \frac{b}{n^2}\right)^2}$$

not only the convergence wave-length but the constant "a" may be computed from the atomic radii. In the case of gaseous elements whose atomic volumes are not known this gives still two methods of computing atomic radii.

RECENT STELLAR SPECTROSCOPIC RESULTS: *Walter S. Adams.*

This paper contains some recent determinations of stellar parallaxes by the spectroscopic method, including observations on stars of measured parallaxes and Barnard's star of very large proper motion. Also results for the radial velocities of some of the large proper motion stars of low luminosity, and a discussion of their motions with relation to spectral type. Reference is made to a few spectroscopic binaries of exceptional interest.

THE MEASUREMENT OF CLOSE PAIRS OF SOLAR LINES:

Charles E. St. John and *L. W. Ware.*

This is a study of the errors of measurement of close pairs of solar spectrum lines based on plates taken under different conditions, in different orders, with a scale ranging from 1.8 to 0.25 angstrom per mm, and measured by two or more observers by means of micrometer settings on the maxima and on the edges of lines and by microphotometer curves.

Whenever lines are so close together that the background between them differs in intensity from the continuous background, a tendency toward over-separation appears, more marked for the closer pairs. For pairs with components of intensity 3 or 4, the limit below which the effect is felt in micrometer measures is from 0.10 to 0.15 A for the region investigated, λ3900—λ5270, being less for the sharper cut lines at the blue end. Any condition operating towards loss of sharpness in definition—a widening of the slit, a change from best focus, exposure or development not adapted to the lines under consideration—tends to increase the error. That the last of these affects the Rowland plates, exposed and developed for the general run of lines, is probable, and would explain differences such as those found for the 22 pairs studied; namely, 0.003, 0.008 and 0.013 A for mean separations of 0.276, 0.145 and 0.075 A, respectively.

The difference in contrast for the two edges of a component of a close pair, when one edge is seen against the dense background of the continuous spectrum and the other against the less dense region of overlap between the two components, shifts the estimated position of the maximum of such a line towards the side of greater contrast. The result is a measured separation slightly too large, but important because systematic.

THE SUGGESTED MUTUAL INFLUENCE OF FRAUNHOFER LINE: *Charles E. St. John.*

The mutual influence of Fraunhofer lines is an accepted deduction from the anomalous dispersion hypothesis. For closely adjacent lines the assumed dissymmetry of the dispersion bands is such that the violet and red components of close pairs are displaced to the violet and red, respectively; that is, the separation is greater in solar than in arc spectra.

The mean Sun — arc displacement for 213 stable iron lines of groups *a*, *b*, and *c4* of the Mount Wilson classification is +0.0039 A; that for 30 lines with companions at an average distance of 0.31 A to the red is +0.0042 A; that for 59 lines with companions at an average distance of 0.27 A to the violet is +0.0040 A. The three values being equal within the limits of error shows the absence within these limits of mutual influence.

The separations of the components in 45 close pairs have been measured upon separate plates for the Sun and arc. The mean separations in solar and arc spectra are 0.231 and 0.232 A, respectively. The equality shows again the absence of a measurable mutual repulsion.

A comparison of the Rowland and International wave-lengths of the iron lines shows for the violet and red components of close pairs apparent displacements of 0.007 and 0.005 A to the violet and red, respectively, (Albrecht). The wave-lengths of the 104 lines used by Albrecht have been measured upon plates of high dispersion with neighboring isolated lines as standards. These indicate errors in Rowland which are systematic, the violet and red components of close pairs having tabular values respectively too small and too large. Large and small Rowland errors correspond to large and small Albrecht deviations, the coefficient of correlation being +0.56 ±0.05. The probable explanation is that the errors and deviations are two phases of the same phenomenon. The deviations do not then furnish valid proof of mutual influence, while the Sun — arc displacements and the equality of separation in solar and arc spectra indicate its absence within the limits of error.

Observations With High Dispersion of the Line λ 6708 in Laboratory and in Sun-spot Spectra: *Arthur S. King.*

An extended series of experiments with the arc and the electric furnace have shown that the line λ 6708 is in all cases due to lithium, the hypothesis that calcium under certain conditions might show such a line being disproved. The line is highly complex, two distinct sets of components appearing as the amount of vapor in the source is changed.

Measurements of a strong line in the spectra of sun-spots showed so close an agreement with the laboratory measures of λ 6708 as to leave little doubt that lithium is present in the solar atmosphere, tho apparently able to show its spectrum only in the cooler regions over sun-spots.

Note on Barnard's Proper Motion Star: *R. G. Aitken.*

Micrometer measures were made with the 36-inch refractor on June 14 and June 20, connecting Barnard's remarkable proper motion star (R. A. 17^h 54^m; Decl. + 4° 27′) with the 8.7 magnitude star, B. D. + 4°.3560, which precedes it and with two 13th magnitude stars which follow it. These measures were repeated on the nights of July 22 and 26. From these measures, covering a period of 37 days, an annual proper motion of 9″.48 in position angle 344°.34 results.

Miss Jessica M. Young has compared two plates of this star taken with the Crossley reflector on June 20 and July 20, and has deduced an annual proper motion of 8″.84 in 354°.14.

These results are of interest in showing the possibility of obtaining approximately correct values of the proper motion of this remarkable star in a period of only one month.

As seen in the 36-inch refractor, the star has a decided orange color and is about 10.5 magnitude.

Note on the Spectral Type and the Radial Velocity of Barnard's Proper Motion Star: *W. W. Campbell and J. H. Moore.*

See page 207.

A LUMINOUS OBJECT SEEN ON MAY 4, 1916: *C. D. Perrine.* See page 176.

A LUMINOUS OBJECT SUSPECTED TO BE A COMET: *A. Estelle Glancy.* See page 179.

RECENT OBSERVATIONS OF THE DIURNAL CHANGE IN THE REFRACTION, AT LICK OBSERVATORY: *R. H. Tucker.*

The purpose of the observations is to check the existence of the diurnal change in refraction, which was found in the reductions of earlier fundamental observations, and to fill in the interval of three hours each side of noon, for which determinations were lacking. The discussion of the diurnal change was first published in *L. O. Bulletin,* No. 231, in 1913.

For the noon values, *Polaris* and *β Ursæ Minoris,* at lower culmination, have been generally employed, as most stars at lower altitudes are invisible in full daylight near noon. A list of over twenty stars of large zenith distances, both north and south, has also been observed, giving determinations of the refraction, from four hours preceding sunset up to nearly midnight.

The results confirm the values derived from the fundamental observations of 1905 and 1906. Observations of zenith distance made here indicate a correction to the Poulkova Refractions of approximately —0″.2 tan Z. D. for the night work. The correction begins to diminish before sunrise, changes sign, and reaches a value of approximately +0″.3 tan Z. D. in full daylight.

The change sets in, with reversed sign, before sunset, continuing until the mean value for the night is reached.

Diagrams show the variations, both by plotting the values of individual sets, and by combining all the observations into hourly means.

The total variation is about one per cent of the refraction correction.

The important requirement of such an investigation is to free the results from the effect of any other sources of systematic error. Thus the error of standard star declinations must be considered, and must be eliminated. Graduation errors, variations of nadir reading, latitude variation, flexure and bisection errors must be similarly treated. Also the question of atmospheric dispersion, affecting the images of bright stars at low altitudes, has been investigated.

PRELIMINARY NOTE ON THE DETERMINATION OF THE LONGITUDE OF THE STUDENTS' OBSERVATORY BY WIRELESS SIGNALS FROM ARLINGTON: *R. T. Crawford.* See page 208.

THE CHABOT OBSERVATORY: *Charles Burckhalter.*

The Chabot Observatory was presented to the Board of Education of Oakland in 1884, by Mr. Anthony Chabot, and was to be forever free to the public and public schools; the cost was about fifteen thousand dollars. The location was, unfortunately, in the heart of the city. In a few years, when electric lighting was in general use, certain kinds of work could not be carried on until after midnight, and, later, not at all. Then the director asked the Board of Education to move the Observatory to a favorable location, or close it entirely. Also, if moving prevailed, to add a large telescope, as the eight-inch, while a fine telescope, had come to be only of very moderate size, on account of the great increase in size of later instruments. Both recommendations were approved, and, as soon as possible, the telescope was ordered.

The successful bidder was the Warner & Swasey Co. for $19,100. The telescope has a clear aperture of twenty inches, with a focal length of twenty-eight feet. The objective is of Jena glass; the disks, in leaving Germany, missed the British blockade by only three days.

Mr. Brashear, the maker, declares it to be fully the equal in light-grasp to any twenty-five inch lens of the glass heretofore used. This would leave but four refractors in this country that exceed it. The instrument was finished in time to form part of the exhibit of the Warner & Swasey Co. at the Exposition.

Five sites were offered to the Board, free, and the Park Commission offered any site in the City Parks, but none of them was altogether satisfactory. A site was finally secured for $6000 that is nearly ideal. It is shielded from the city light by an intervening ridge, and the topography of the surrounding conditions is such that no future buildings can seriously interfere with the Observatory. It is freer from fog than any part of Oakland, and has a twenty-minute street car service, with five-cent fare.

The site contains twelve acres, to which future streets will add four more.

The building is far enough advanced to use the telescope and it is expected to continue to completion as soon as the budget for the present fiscal year has been passed.

NOTES ON CERTAIN DOUBLE STAR ORBITS: *R. G. Aitken.*

A revised orbit of β 1111, based on an observed arc of 210° was presented. The elements are:

$P = 39.2$ years
$T = 1917.67$
$e = 0.33$
$a = 0''.23$
$\omega = 127^\circ.9$
$i = \pm 40.7$
$\Omega = 59.0$

This orbit, which offers no difficulties to the computer, was shown as a contrast to the orbits of double star systems in which the inclination of the orbit plane is nearly, but not quite, 90°, and the eccentricity quite high.

Systems of this type, of which there are many representatives, present a maximum of difficulties to the computer, and it is generally impossible to calculate a satisfactory orbit until the completion of at least one revolution. Half a dozen examples were shown, including Σ 1865, ζ *Bootis*, for which a first orbit was given, on the assumption that the companion is now in the fourth quadrant. The resulting elements are:

$P = 139$ years
$T = 1898.5$
$e = 0.96$
$a = 0''.89$
$\omega = 48^\circ.8$
$i = \pm 62.0$
$\Omega = 158.8$

Except for the eccentricity, these elements are quite uncertain, and the uncertainty is principally due to the lack of measures at the time of minimum separation and to the discordance of the observed distances.

The writer believes that the practice of making measures under poor observing conditions or with inadequate instruments is largely responsible for the discordant observations.

COMET *b* 1916 (Wolf): *R. T. Crawford* and *D. Alter.* See below.

NOTE ON AETHRA: *D. Alter.* See page 210.

JOHN WINTHROP (1714-1779), AMERICA'S FIRST ASTRONOMER AND THE SCIENCE OF HIS PERIOD: *F. E. Brasch.* See page 153.

NOTES FROM PACIFIC COAST OBSERVATORIES.

COMET *b* 1916 *(Wolf).*

The second comet of the year 1916 was discovered photographically by Wolf at Heidelberg, the evening of April 27th. It is of peculiar interest in several respects.

After the announcement of the discovery Professor Barnard at the Yerkes Observatory found that he had the object on plates he had taken three nights previous to the discovery plate of Wolf. This observation of April 24 is the earliest one available.

The computations show that at discovery the comet was about 4.1 astronomical units distant from the Earth and nearly 4.9 astronomical units from the Sun, distances greater than those of any other comet at the time of discovery. Even Halley's Comet, whose position for its last return was quite accurately known, was picked up on this return when a little over three astronomical units away. It was found eight months before its perihelion passage date, while Wolf's Comet, altho unexpected, was discovered nearly fourteen months before it will come to perihelion.

On account of the great distance at the time of discovery and the consequent slow motion of the comet, a large range of solutions was possible for orbits that would represent the early observations. This was very apparent in the progress of the first computations. Were it not for the fact that the observations are of an unusual degree of accuracy a much longer arc than was used would have been necessary to obtain even an approximate idea as to the true character of the orbit. The orbit computed at the Students' Observatory in Berkeley is based upon observations of April 24th, May 10th, and May 23d. This, together with an ephemeris extending to August 29, has been published in *Lick Observatory Bulletin* No. 282. From the manner in which later observations are represented by this orbit it will be noted that these elements are very satisfactory for a preliminary orbit and show very approximately the character of the path. They are undoubtedly good enough to furnish a place for finding the comet again about the first of December, 1916, after it will have passed conjunction (the latter part of October). A second orbit will therefore not be computed here until after the comet has been observed again in December. An ephemeris based upon the present elements will be computed beginning about the first of December when the comet will be a morning object about an hour and twenty minutes ahead of the Sun.

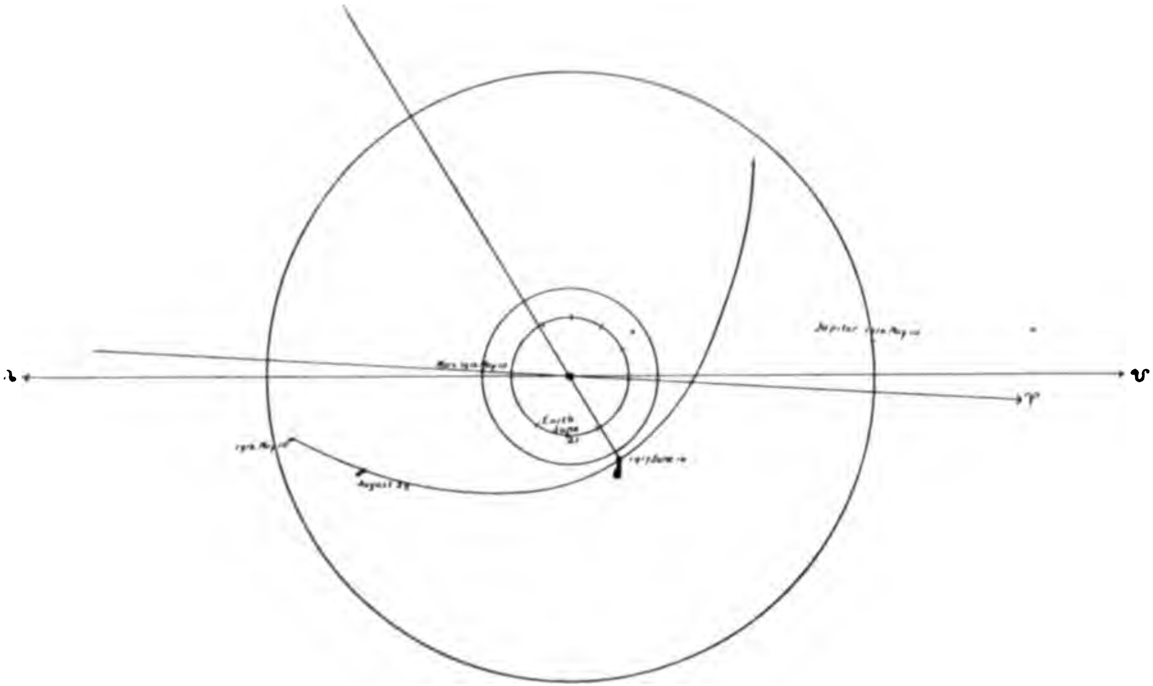
Referring again to the range of solutions, a brief sketch of the course of the computation may be of interest. The first three observations available here were those of April 24th, May 4th, and May 10th. We had just computed an orbit based upon these observations when Van Biesbroeck's elliptic elements were received. Ours was a parabola with an inclination of 95° and giving a perihelion date in 1914. This parabola represented very satisfactorily not only the three observations upon which it was based but also another observation by Barnard made May 6th. These two sets of elements were so radically different that it was decided to withhold our parabola and wait for another observation giving a longer arc. Cloudy weather at Mount Hamilton prevented our obtaining an observation from the Lick Observatory, but Director Frost of the Yerkes Observatory kindly sent us one of May 23d by Van Biesbroeck. Using this and the observations of April 24th and May 10th the elements referred to as giving the character of the orbit were computed.

As Van Biesbroeck's elliptic elements (short period) also gave a satisfactory representation of the early observations it was decided to investigate what period would be possible for an ellipse to give a satisfactory representation of the observations from April 24th to May 23d. We used Leuschner's Method of Conditioned Solutions, wherein an orbit of any chosen period can be forced thru three right ascensions and two declinations, leaving the representation of the remaining declination to show the degree of satisfaction of the conditioned solution.

Using a period of seven years the orbit came out practically the same as Van Biesbroeck's, but left a residual of 31″ in the first declination (the one not used in the solution). Adopting a period of fifty years the residual in the first declination amounted to 7″. As this is about the limit of accumulated error of observation allowable in the three observations (as mentioned, they are of a high degree of accuracy) it can be safely said that the available observations can not be represented satisfactorily by an ellipse with a period much less than fifty years. The observations used are perfectly represented by an orbit slightly hyperbolic. We can therefore safely say that for the observations at hand the range of possible solutions is from an ellipse with a period of about fifty years to an orbit slightly hyperbolic.

An inspection of the drawing of the orbit of the comet together with the orbits of the Earth, *Mars* and *Jupiter* will reveal several interesting points. In this drawing the inclination of 25° to the ecliptic has been neglected.

It will be seen that at discovery the comet was nearly at *Jupiter's* distance from the Sun. The position of the Earth at the time was such that for a few months following discovery time the distance between the comet and the Earth varied but little; they were traveling in nearly the same direction, and the Earth going the faster made the geocentric distance increase. Conjunction will be reached the latter part of October. The comet will undoubtedly be lost in the twilight early in September. After conjunction the comet will probably be reobserved as a morning object in December.



Wolf's Comet 1916

The differences in right ascension between the comet and the Sun at this time are as follows:

1916 Gr. M. T.	$\Delta\alpha$ (☉ — Comet)	Br.
Nov. 29.5	1h 16m	2.96
Dec. 7.5	1 37	3.32
Dec. 15.5	1 59	3.74
Dec. 23.5	2 20	4.25
Dec. 31.5	2 41	4.86

Brightness May 10 = 1.00.

From this time on the brightness will increase rapidly and the comet will be in favorable position for observation during the whole of the year 1917, coming to opposition soon after perihelion passage, which occurs 1917, June 16, at which time the comet will probably be visible to the unaided eye. It will be visible for telescopic observation until February or March, 1918, when it will again be lost in the Sun's light, approaching conjunction. By July or August, 1918, it is probable that the comet can again be picked up and observed with large telescopes during the remainder of that year, when it will be about as bright as at discovery. From these facts it is seen that the comet will be observable over a stretch of nearly three years.

For the sake of completeness the elements published in *Lick Observatory Bulletin No. 282* are repeated here:

$$T = 1917 \text{ June } 16.4806 \text{ Gr. M. T.}$$

$$\left.\begin{array}{l} \omega = 120^\circ\ 37'\ 07''.9 \\ \Omega = 183\ \ 16\ \ 58\ .8 \\ i = \ \ 25\ \ 40\ \ 06\ .4 \end{array}\right\} 1916.0$$

$$\log q = 0.226855$$

It may be added that the plane is oriented so that its inclination to the equator is only 2° 36′.

To show how well our orbit is holding and to attest to the great accuracy of the observations at hand at the present time the following table of observations made since May 23 together with their representation by the orbit is here given:

1916 Gr. M. T.	Comet's apparent α	Comet's apparent δ	(O—C) $\cos\delta\Delta\alpha$	(O—C) $\Delta\delta$	Observer
May 27.6893	12h 29m 48s.6	+4° 18′ 17″	—0s.1	0″	Barnard
27.7933	12 29 47 .4	4 18 30	—0 .1	—2	Aitken
28.6536	12 29 38 .8	4 20 28	+0 .1	—2	Van Biesbroeck
May 30.7009	12 29 19 .9	4 24 51	+0 .1	—2	Van Biesbroeck
June 4.7197	12 28 47 .9	4 33 47	+0 .1	+1	Van Biesbroeck
17.6493	12 28 59 .2	4 45 12	+0 .2	+1	Barnard
21.6709	12 29 30 .2	4 45 27	+0 .1	0	Barnard
24.6369	12 30 01 .3	4 44 43	+0 .3	+1	Barnard
June 28.6400	12 30 54 .2	4 42 27	+0 .1	—1	Barnard
July 1.6559	12 31 42 .7	4 39 49	+0 .2	—1	Barnard
July 5.6369	12 32 57 .2	+4 35 11	+0 .3	—1	Barnard

R. T. CRAWFORD,
DINSMORE ALTER.

Berkeley Astronomical Department,
July 17, 1916.

NOTE ON THE SPECTRAL TYPE AND THE RADIAL VELOCITY OF BARNARD'S PROPER MOTION STAR.

We have obtained spectrograms of Barnard's proper-motion star (R. A. = 17^h 54^m, Decl. = +4° 27′) with the 36-inch refractor, the collimator section of the original Mills spectrograph, a 60° prism of light flint, and a 6-inch camera, on Seed 30 plates, as follows:

Gr. M. T.	Exposure	Observers
1916 June 19.845	7^h 20^m	Campbell & Moore
July 31.813	6 55	Shane & Paddock

The length of spectrum is 6 mm. from calcium K to hydrogen Hβ. One mm. at Hγ corresponds to 154 angstrom units.

The first exposure recorded the spectrum in measurable strength from 4390A to the red of Hβ, and showed that the type is Class Mb. The second exposure recorded the star spectrum to 4000A as the violet limit, and in measurable intensity from 4300A to about 5000A. To enable us to measure the displacements of the lines and bands on the Hartmann spectro-comparator, we photographed the spectrum of α *Herculis* (R. A. = 17^h 10^m, Decl. = +14°.5, Class Mb, known radial velocity —32 km./sec.) with the same instruments.

The results of the measures for radial velocity are, with reference to the solar system:

1916, June 19	Measurer
—134 km./sec.	Campbell
—104 "	Moore
—114 "	Moore
—117 "	Weight 1/2

1916, July 31	Measurer
—149 km./sec.	Campbell
—123 "	Moore
—131 "	Moore
—134	Weight 1
—128 km./sec.	Weighted mean

The first plate is given half weight because the seeing was poor, there was some interference from clouds, and the Moon's light (four days past the full) may have affected the plate very slightly.

A comparison of the spectrograms of α *Herculis* and Barnard's star shows general agreement of spectral class, but discordances in the relative intensities of several absorption lines. We note the following differences:

Line	In α *Herculis*	In Barnard's star
4227 Ca	very strong	much weaker
4435 Ca	strong	stronger
4455 Ca	strong	much stronger
4535 Ti	strong	stronger
4395	fairly strong	apparently weaker
4404	fairly strong	apparently weaker

The differences described are apparently the indications, according to Adam's discovery, that α *Herculis* is a "giant" star at a great distance from us and Barnard's star a "dwarf" comparatively near us. A 20-hour exposure on the spectrum of Barnard's star, using a 16-inch camera in combination with the 60° prism, would probably permit a valuable estimate of the parallax of the star to be made, by the Adams method; but unfortunately the requirements of our other programs prevented the devotion of twenty hours to this purpose.

Assuming that the B. D. star +4°.3560, which follows Barnard's star by 9 seconds of time, has visual magnitude 8.7, the visual magnitude of Barnard's star must be approximately 10½. Taking the color index of stars of spectral class Mb to be 2, the photographic magnitude of Barnard's star is therefore about 12½.

W. W. CAMPBELL.
J. H. MOORE.

PRELIMINARY REPORT ON THE DETERMINATION OF THE LONGITUDE OF THE STUDENTS' OBSERVATORY BY WIRELESS SIGNALS FROM ARLINGTON.

In the spring of 1914, while Washington and Paris were conducting their longitude campaign by exchange of wireless signals between Arlington and the Eiffel Tower, an attempt was made to determine the difference in longitude between the Students' Observatory at Berkeley and the U. S. Naval Observatory at Washington by intercepting the Arlington signals.

No signals could be heard until the top of the Sather Campanile (for which the steel frame was just then completed) was used for one support of the receiving aerial. After the aerial had been strung from the Mechanics Building to the top of the Campanile the Arlington signals could be received. However, the regular Paris-Arlington signals came along about 4 P. M., at which time there was so much wireless business being done on the Pacific Coast that these signals could not be detected with certainty. Recourse had then to be had to the 10 P. M. Arlington signals (7 P. M. P. S. T.). These signals were observed on several nights, but only those were used which came on nights when accurate observations for local sidereal time were obtained with the new Bamberg Transit and the registering micrometer, so that we did not have to trust to the rate of the chronometer which was somewhat irregular. Six such sets of observations are available.

The Washington local mean time of sending these signals has been kindly furnished by Captain J. A. Hoogewerff, U. S. N., Superintendent of the U. S. Naval Observatory.

The results of these six nights' observations are exhibited in the following table:

Date 1914	U. S. Naval Obsty. Local Mean Time Sending	Students' Obsty. Local Mean Time Receiving	Diff. of long **Wash'n-Berkeley**	**Wt.**
Feb. 21	$9^h\ 51^m\ 44^s.21$	$6^h\ 50^m\ 57^s.17$	$3^h\ 00^m\ 47^s.04$	3.0
27	44 .23	57 .16	47 .11	3.7
Mar. 3	44 .21	57 .17	47 .04	3.7
6	44 .28	57 .30	46 .98	2.6
15	44 .27	57 .16	47 .11	4.2
Apr. 19	44 .41	57 .34	47 .07	2.6

Weighted mean . . . $3^h\ 00^m\ 47^s.06 \pm 0^s.03$

The weights assigned have been computed as the square root of the product of the number of coincidences observed in receiving the signals by the number of stars used in the local time determination of the night.

The Washington-Greenwich longitude used is $5^h\ 8^m\ 15^s.78$. Using this and the value of Washington-Berkeley just found, we have for the longitude of the Students' Observatory, Berkeley, referred to Greenwich, $8^h\ 9^m\ 2^s.84$.

Using the value of the longitude of Washington found from the Washington-Paris work, *viz:* $5^h\ 8^m\ 15^s.72$, we would have $8^h\ 9^m\ 2^s.78$ as the longitude of Berkeley. Captain

Hoogewerff writes that the latter value of the longitude of Washington has not yet been adopted for use.

Captain Hoogewerff writes further that times of sending the 10 P. M. signals cannot be connected up with the Washington-Paris work very rigorously "on account of the different relay lags involved, that at Radio sometimes amount to about $0^s.01$."

The value $8^h\ 9^m\ 2^s.84$ agrees very well with that used here for several years past (*viz:* $8^h\ 9^m\ 2^s.82$) which was determined by connecting up with the U. S. Coast and Geodetic Survey Observatory in San Francisco.

Because of the uncertainty, mentioned by the Superintendent of the U. S. Naval Observatory, due to the possible relay lags, the value of the longitude of the Students' Orservatory heretofore used, *viz:* $8^h\ 9^m\ 2^s.82$, will be continued as the adopted mean value until further notice.

In this campaign the radio work was ably conducted by Messrs. R. B. Abbott of the Department of Physics, and H. F. Fisher and F. E. Pernot of the Department of Mechanical Engineering. The local time determinations were made by Messrs. R. T. Crawford, S. Einarsson, and S. B. Nicholson of the Berkeley Astronomical Department. The whole campaign was directed by Professor A. O. Leuschner, Director of the Students' Observatory.

R. T. CRAWFORD.

Berkeley Astronomical Department,
July 28, 1916.

ON THE ORBIT OF (132) AETHRA.

The minor planet *Aethra* was discovered by Watson in 1873. Watson observed it on six nights, and Borrelly, Coggia and Stephan of the Marseilles Observatory on seventeen consecutive nights until the fifth of July. Since then it has not been seen.

Widely differing orbits were published by Watson and later by Luther. The values of the mean daily motion for these range from 843″ to 980″. Luther's work included the computation of the orbit upon several assumptions of the mean motion. He computed ephemerides for several consecutive years and some search was made on the basis of them, but the results were negative.

In 1913 an object was photographed with the 40-inch reflector of the Lowell Observatory. Later this was suspected as *Aethra,* but unfortunately there was but the one observation.

In the fall of 1914 an investigation of the orbit was begun by the writer. The range of the mean daily motion within which a satisfactory representation could be obtained was very carefully investigated. It was found that any motion between eight and nine hundred seconds of arc represented so closely that, when the discrepancies of the observations were considered, there was an almost equal probability for any of the values. Indeed a much larger range was found to be possible.

An investigation of the Lowell observation showed that it could be represented closely by an orbit based on the 1873 observations, merely choosing that mean motion which best satisfied its right ascension. On the basis of this orbit an ephemeris was computed for the last opposition. Cloudy weather interfered with the search at the Lick Observatory and the writer does not know of any other being undertaken.

The above investigation was published as Number 275 of the *Lick Observatory Bulletins.* Since that time the work has been continued and has yielded one or two quite interesting results.

A slight error was found in the adopted value of the mean daily motion required to represent the 1913 observation. This error changed the value by only four one-hundredths of a second of arc. The new value represents the declination more closely than the one printed, thereby increasing the probability of identity, for when an orbit is obtained, as described above, the reciprocal of the δ-residual is a fair measure of the probability of the final observation being of the same object as those on which the orbit is based.

On the supposition of identity between *Aethra* and the object observed at the Lowell Observatory, it is found that the mean daily motion of *Aethra* differs less than four seconds from one-fourth that of the Earth. As a result of this near commensurability, oppositions at which the planet is near perihelion must occur at the same time of year during long periods of time. Perihelion is in that part of the orbit where the planet is far south of the ecliptic. In the case of *Aethra* both these conditions combine to cause the planet to be always far south of the equator when near perihelion. The great eccentricity of the orbit makes this a very serious matter for observers in the northern hemisphere. For such oppositions as last year, when the planet is far north, the nearness to aphelion causes it to be faint. When it is bright it is many degrees below the equator. This explains one of the facts that has puzzled those who have studied the orbit. How could a planet which becomes as bright as *Aethra* does at times miss accidental observation during a period of forty years? By explaining this circumstance it seems to the writer that the probability of identity is much increased.

An ephemeris has been computed for the coming opposition. On December 1st the declination will be —24° and the magnitude 10.6, which is brighter than it was at any time last year. February 1st it will be 41° south and will have a magnitude of 10.3. During March and the early part of April it will be about 45° south and have a magnitude of about 10.0. It then begins its return north, coming to opposition about May 1st, 42° south of the equator with a magnitude of 9.9. These magnitudes are based on the 1873 visual observations and, according to the Lowell observation, should be somewhat brighter.

It is worth while to note that the coming opposition is similar to those in 1873, when it was discovered, and in 1913 when it is assumed to have been reobserved. It will be very easy, especially for southern observatories, to make a search that will settle the question of identity. Northern observatories can best search for it in December, five months before it comes to opposition.

DINSMORE ALTER.

Students' Observatory,
University of California.
1916, July 20.

DELICATE EARTH TREMORS.

On the night of August 18, 1916, a continuous series of tremors was noted, while attempting to observe over the nadir for level of the meridian circle. The tremors lasted for at least five minutes, between $8^h\ 52^m$ and $8^h\ 57^m$ P. S. T., beyond which interval other duties required the observer's attention. Fifteen minutes later the mercury was quiet and the vibration had evidently ceased. The period of the tremors was short, less than one second; and the amplitude was estimated at about two seconds of arc. Both amplitude and period were shorter than tremors of a similar character that had been previously noted in this manner, and which were associated with earthquake shocks, either of moderate intensity in the neighborhood of the observatory, or of severe intensity at greater distances.*

No vibrations are recorded on the sheet of the large Wiechert Seismograph of the observatory, and it appears to be probable that the indication given by the basin of mercury is more delicate than that of any instrument depending upon the disturbance of the equilibrium of a balanced weight.

Since a second of arc corresponds to about the two-thousandth part of an inch, over the mercury basin, the amplitude of the vibrations was of the order of the thousandth part of an inch. But, as the tremors noted are most likely to be in the form of waves passing over the surface, the amplitude does not correspond exactly to the amount of disturbance in the strata below.

Such tremors in the mercury are entirely different from those produced by a shock in the rock supporting the instrument, or from those produced by wind. They are undoubtedly an indication of vibration in the rock strata, and are believed to be connected with some earthquake, perhaps too slight to be detected by other means.

August 21, 1916.

R. H. Tucker.

Addendum to Note on the Internal Velocities of Nebulæ.

In the last number of these Publications, pages 119-120, in a note concerning observations of relative velocity within each of six planetary nebulæ, we referred briefly to the remarkable form of the bright lines in the spectrum of the nebula N. G. C. 2392 ($\alpha = 7^h\ 23^m.3$). The particular observation referred to was made by us on the evening of April 7, 1916, with 3-prism dispersion and a 16-inch camera in the regular progress of the program which we had made out for determining nebular rotations or relative motions within nebulæ. On the forenoon of that day, after our detailed plans for observing this object that evening had been made, Mr. Wright informed us that his 1-prism spectrogram of N. G. C. 2932, obtained several nights earlier on a fine-grained plate, showed nebular lines strongly curved, indicative of a high velocity of the central part of the nebula with respect to the ring. Spectrograms of the same nebula, obtained by him on coarse-grained plates in the years 1914 and 1915, showed corresponding distortions. Our published paragraph on the subject should have stated these facts. The oversight probably arose from the preparation of the article at the last minute before the manuscript had to go to the printer.

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*Science, 1900, Vol. XI, p. 217.

*Pub. Astr. Soc. Pac. 1894, Vol. VI, p. 184.

W. W. Campbell,
July 7, 1916. J. H. Moore.

GENERAL NOTES.

Dr. J. C. Duncan, Instructor in Astronomy at Harvard College and formerly a Fellow at Lick Observatory, has been appointed Professor of Astronomy and Director of the Observatory at Wellesley College.

The new Van Vleck Observatory of Wesleyan University was dedicated on June 16, 1916, and the addresses given on this occasion will be found in the August-September number of *Popular Astronomy*. The new observatory is the gift of Joseph Van Vleck in commemoration of his brother, John M. Van Vleck, who was Professor of Mathematics and Astronomy at Wesleyan for nearly sixty years. Dr. Frederick Slocum is Director of the Van Vleck Observatory, which, in addition to its use in connection with the work of instruction at Wesleyan, will devote its energies mainly to the determination of stellar parallaxes. The main instrument is an excellent 18½-inch refractor, mounted by Warner and Swasey, and equipped with a rising floor. The completion of the lens has been delayed by the war, and the 12-inch lens from the old observatory will be used temporarily in the new mounting. The observatory possesses in addition two 3-inch transits and a very complete outfit of minor instruments and attachments for the work of instruction and research.

The nineteenth meeting of the American Astronomical Society will be held in the Sproul Observatory at Swarthmore, Pennsylvania, August 30 to September 2, 1916. This is the first time since 1911 that the Society has met east of the Alleghenies. A good attendance and a full complement of papers and reports is expected.

A Coincidence.—In a note to the editors, Dr. C. D. Perrine calls attention to a remarkable coincidence. On May 3, 1916, he telegraphed to the Harvard College Observatory two observations made by Dr. Glancy at the Argentine National Observatory, Córdoba, which were supposed to be of Wolf's newly discovered comet. Observing conditions on both nights were quite unfavorable. On the night of May 3d, with good observing conditions, it was found that the two objects observed were faint nebulæ, similar in size and form, the second one slightly brighter, which were so placed as to correspond closely to the positions to be expected from the data at hand of Wolf's Comet on the two nights!

A telegram of correction was at once sent out.

Recent Publications.—Number 18, Part 2, of the *Publications of the Cincinnati Observatory* has recently been distributed. It contains Part II of the catalog of proper motion stars, including the stars to fifteen hours right ascension, of which a notice was printed on p. 248 of Volume XXVII of these PUBLICATIONS.

Another volume of interest is Volume XXI of the Resultados del Observatorio Nacional Argentino, containing the extension of the well-known Córdoba Durchmusterung thru the zone from —52° to —62°. About ninety per cent of the observations for this volume were made under the direction of the late Dr. Thome, and Dr. Perrine has made every effort "to carry out Dr. Thome's plans of work as far as they could be known."

REVIEW.

ANNALS OF THE DEARBORN OBSERVATORY, NORTHWESTERN UNIVERSITY. VOLUME I. MEASURES OF DOUBLE STARS, BY PHILIP FOX.

It is fitting, as Professor Fox says, that the first volume of publications of the Dearborn Observatory should be one of double star measures, for the 18½-inch refractor was made famous by the discovery with it of the companion to ***Sirius*** by Mr. A. G. Clark, and by the work of Burnham and of Hough in the discovery and measurement of a large number of double stars.

The introduction consists of an interesting historical account of the Chicago Astronomical Society which purchased the telescope in 1863 and founded the Dearborn Observatory. It will probably be a surprise to many astronomers to read that this society is still in active existence and that the title to the telescope and other instruments of the observatory remain in it. The society itself, however, by the terms of an agreement adopted in 1887, became, with the observatory and instruments, a department of the Northwestern University.

Following this historical sketch comes an account of Professor Fox's investigation of the 18½-inch objective. He tested the lens by the Hartmann method and found that the focal length for the center and edge is somewhat shorter than for the intermediate zones. Such abnormal zones as exist in some other large objectives are absent from the 18½-inch, and the test confirms the excellence of the lens, which had, in fact, been fully established by the discoveries made with it. The color-curve of the objective was also determined and was found to be similar to those of the best visual objectives.

The double star measures, all made by Professor Fox, fall into four parts, the first two being complete series of measures of the pairs discovered by Professors E. S. Holden and F. Küstner, respectively; the third, a long series of measures of miscellaneous stars, and the final one a short series, of pairs discovered by the author. In general each pair was measured on three or more nights, a single night's measure consisting of four settings for position angle and three or more settings for double distance. The accordance of measures shows that the error of measure is small and that these observations will rank with the best of double star measures.

More distant companions for many of the pairs have been measured, principally to supply data for proper motion determinations, and the result is that a casual examination of the book leaves the impression that the majority of the measures are of wide pairs. Closer inspection will show that this is not the case. The present writer estimates that the volume contains measures of about 1,500 separate systems and that in about 900 of them the principal pair has an angular separation of less than 5″. More than 100 of them have measured distances of less than 1″, and some of them, *e. g.*, O Σ 79, approach the limit of the telescope's resolving power.

When one reads in the notes such remarks as "Temperature —16 F.", "Temperature —8 F.", etc., one admires the enthusiasm that warms the observer but congratulates one's self on being located in a milder climate. Other notes relate to the character of the motion, to questions of identification and to questions of priority of discovery. One or two of the latter notes seem to point to a belief on the author's part that priority should be established by the date of first observation. There are arguments in favor of this view, but the present writer is strongly of opinion that the date of publication should decide. Earlier observations of newly announced double stars, as of comets, proper motion stars, etc., are of great interest and value, but do not affect the question of priority.

In the Introduction, it is stated that Professor Safford undertook to observe the zone from +40° to +45° declination for the A. G. Catalog. This, as Professor Fox writes me, should be +35° to +40°. Another error is found on p. 153, where Σ 2084 is called ξ *Herculis* instead of ζ.

It may be aded that the pair Fox 32, given as new on p. 226, is identical with A 2278.

The volume forms a notable addition to our double star literature, and it is a pleasure to know that further work of the same high quality is in prospect.

R. G. Aitken.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC.

Held in the Rooms of the Society on June 27, 1916, at 2:15 p. m.

There were present Directors Cushing, Curtis, Cornish, Markwart and Richardson. Cushing in the Chair.

A resolution was introduced by Director Curtis providing that the Regular Meeting of the Society for the month of June be omitted. Carried.

Colonel Thomas L. Casey, U. S. A., was elected a Life Member of the Society.

The following were elected as Active Members:

Frederick A. Wilson,
Lorenzo L. Snow,
D. S. Swan,
Bernard Bienenfeld,
Hans B. Bauer.

The following were elected as Student Members:

F. J. Neubauer
and
C. D. Shane.

The Smith College Observatory, of Beloit, Wis., was elected as an Institutional Member.

Adjourned.

D. S. Richardson,
Secretary.

OFFICERS OF THE SOCIETY.

S. D. Townley	*President*
C. S. Cushing	*First Vice-President*
H. D. Curtis	*Second Vice-President*
A. H. Markwart	*Third Vice-President*
D. S. Richardson	*Secretary and Treasurer*

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Publication Committee—R. G. Aitken, H. D. Curtis, H. Shapley.
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Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of articles appearing in the *Publications* will be furnished at the following prices:

	4 pp.	8 pp.	12 pp.	16 pp.
50 copies, without covers	$2.00	$4.00	$5.50	$7.00
50 copies, with covers	4.00	6.00	7.50	9.00

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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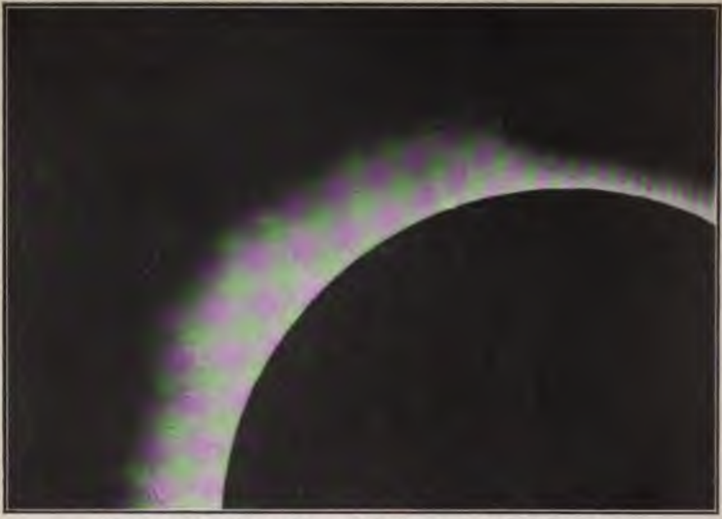

Hoods over Prominence in Southwest Quadrant
Exposure 2^s. Enlarged 2.8 diameters

Corona of February 3, 1916
11-foot camera. Exposure 5^s

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

Vol. XXIX. San Francisco, California, December, 1916 No. 166

THE ADOLFO STAHL LECTURES.

Particular attention is directed to the minutes of the special meetings of the Board of Directors of the Astronomical Society of the Pacific which are printed elsewhere in the present number of these PUBLICATIONS. The generous gift of Mr. Adolfo Stahl, which is there acknowledged, will enable the Society to carry out more efficiently this year than has been possible at any time since the great fire of 1906 one of its chief functions: to stimulate interest in, and promote the knowledge of astronomy by public lectures in non-technical language.

Mr. Stahl has made provision for six such lectures to be given in San Francisco during the present season. The first one of the series, on the subject *The Solar System*, was given by Dr. W. W. Campbell, at the Native Sons' Hall, on Mason Street, on November 10. The dates, subjects, and speakers for the other lectures, which will all be given in the same hall, are as follows:

December 8, 1916, *Comets*, W. W. Campbell;

January 12, 1917, *A Total Eclipse of the Sun*, R. G. Aitken;

February 9, 1917, *Double Stars and Star Clusters*, R. G. Aitken;

March 9, 1917, *The Nebulæ*, H. D. Curtis;

April 6, 1917, *How Astronomical Discoveries are Made*, H. D. Curtis.

All of the lectures will be illustrated by lantern slides and will be free to the public,—in fact, the public is most heartily invited to attend.

The lecture on *The Solar System* follows; the second one of the series, on *Comets*, is printed as the leading article in the current (December)* number of *The Scientific Monthly*; the later lectures, in whole or in part, will be printed in our PUBLICATIONS.

THE PUBLICATION COMMITTEE.

THE SOLAR SYSTEM*

By W. W. Campbell.

The study of astronomy begins naturally with the solar system. The solar system is our abode. It is the observing station from which we look out in all directions to the great stellar system. The solar system is only a minute detail in the structure of the universe. He who would explore the universe should begin by knowing his immediate surroundings. Our visual telescopes could show us sixty or seventy millions of stars, distributed over the whole sky, and our great reflecting telescopes could photograph possibly two or three times as many. With only one exception all of these stars are so far away that they are seen as mere points of light in our most powerful telescope, even when the magnification is nearly 3,000 diameters. The one exceptional star is our Sun. It alone of all the stars can be seen to have a "diameter." It alone of all the stars can be studied in any geometric detail by means now available. This is because our Sun is relatively near to us. The next nearest star known, *Alpha Centauri*, is 275 thousand times as far away from us as our star is. If we would know what the stars in general are we should begin by learning about our own star. That is the chief reason why there are solar observatories in many countries of the world. Those institutions are occupied wholly or chiefly in the study of the Sun. Our Sun is an exceedingly interesting body in itself, especially for beings who live in the solar system, but its main interest to astronomers lies in the fact that knowledge of conditions existing in our Sun enables us to draw many conclusions concerning conditions existing in millions of other suns.

It is not our purpose to describe the solar system in detail; nor shall we burden the lecture by quoting the enormous distances which separate the heavenly bodies: astronomers do not comprehend them any better than the laymen do. One or two distances, one or two masses, will be sufficient to serve as scale values for the entire system. We shall make it our chief concern to emphasize the characteristic features of the solar system so that we may comprehend the relation of its different members to each other, and the relation of the solar system as a whole to the great stellar system. We shall try to visualize the solar system as it exists in space, highly isolated from all other members of the stellar system.

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* First Adolfo Stahl Lecture, delivered November 10, 1916.

The solar system consists of the great central Sun, the eight[1] major planets and their twenty-six satellites, the more than 800 minor planets or asteroids, the zodiacal light materials, the comets and the meteors. Only one other class of bodies is known to astronomers: the nebulæ. Now many of the nebulæ are far out in the stellar system, and a great many others may be outside of our stellar system. Certainly none of the nebulæ existing today have a direct connection with our solar system.

We have said that the Sun is one of the ordinary stars. Compared with the thousands of other stars visible to the unassisted eye on any clear night, our Sun is merely an average star. Nevertheless it is a very large body. Its diameter is 110 times the Earth's diameter. Its volume is therefore 1,300,000 times the Earth's volume. If the Sun were a hollow shell of its present diameter, we could pour more than a million Earths into it and still leave empty the space between the Earth-balls.

The average density of the Earth is five and a half times that of water. The average density of the Sun is only a quarter that of the Earth; that is, the Sun is forty per cent. more dense than water. From the figures quoted it follows that the mass of the Sun, in other words, the quantity of material that the Sun contains, is 333,000 times that of the Earth. It is this immense mass which gives the Sun its tremendous gravitational power, a power sufficient to maintain the planets in their elliptic orbits around it.

At an average distance of ninety-three millions of miles from the Sun are the Earth and its Moon. The Earth-Moon system revolves once around the Sun in what we have agreed to call our year. To complete the circuit in the year requires the Earth to travel a little more than eighteen miles and a half per second. Between the Earth and the Sun are two known planets, *Mercury* and *Venus*. *Mercury* is a little planet, 3,000 miles in diameter, whose average distance from the Sun is about three-eighths the Earth's distance. It is so close to the Sun that it must travel very rapidly in its orbit, an average of twenty-eight miles per second, to keep from being drawn into the Sun. Relatively few people have seen *Mercury*. It does not get very far away from the Sun, but if observers know when it is going to be at its greatest distance east of the Sun shortly after sunset and west of the Sun shortly before sunrise, they would have no difficulty in seeing the planet as a first magnitude star low in the sky, and small telescopes would show the planet's disc.

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[1] These are the numbers known to exist in the year 1916

The planet *Venus*, whose orbit lies between those of *Mercury* and the Earth, is for those who live on the Earth the most brilliant of all the planets. It is just a shade smaller than the Earth in size. The Earth, as you know, is a little over 7,900 miles in diameter. The diameter of *Venus* is 7,700 miles. Its distance from the Sun is not quite two-thirds the Earth's distance. It requires seven and a half of our months to complete its journey around the Sun.

Going outward from the Earth we come to our interesting neighbor *Mars*. It is fifty per cent. farther from the Sun than we are, and its year is a little under two of our years. Its diameter is slightly more than one-half the Earth's diameter—about 4,200 miles. It is therefore a little larger than *Mercury* and a good deal smaller than *Venus* and the Earth. It has two tiny moons. The smaller one is only eight or ten miles in diameter, and the larger one less than forty miles. The surface areas of these little satellites are smaller than some of the counties in California.

Next in order of distance from the Sun are the asteroids, or little planets. The first one was discovered on the first day of the last century, and up to the present time more than 800 have been found. It is not an uncommon thing for ten or fifteen of these bodies to be discovered in a single year, by means of photography. The first one discovered is, so far as we know, the largest: a little less than 500 miles in diameter. The smallest ones are certainly less than ten miles in diameter.

The largest of our planets is *Jupiter*, whose average distance from the Sun is a little over five times the Earth's distance. *Jupiter's* diameter is eleven times the Earth's. Its volume is therefore thirteen hundred times the Earth's volume, and if that planet were a hollow shell you could pour more than one thousand Earth's into it. *Jupiter* requires nearly twelve years to complete its circuit, at an average speed of eight miles per second. This great planet is known to have nine satellites. The four bright moons, visible even with opera glasses, were the first celestial bodies discovered by Galileo and his telescope—in the year 1610. It is of special interest to Californians to note in passing that the fifth moon of *Jupiter* was discovered with the 36-inch refractor of the Lick Observatory in 1892; the sixth and seventh moons with the Crossley reflector of the Lick Observatory in 1904-5; and the ninth satellite with the Crossley reflector in 1914. The eighth was discovered at the Royal Observatory, Greenwich, in 1908.

Still farther from the Sun is *Saturn* with its wonderful ring system and nine known moons. Its diameter is nine times that of the Earth, and it goes once around the Sun in a little less than thirty years. Maxwell and Keeler proved that the rings are a great collection of little moons—probably millions of them.

The six major planets already named were well known to the ancients. References to them are frequent in the extant literature of the nations, past and present. The planet next in distance, *Uranus*, was discovered by Sir William Herschel in 1781 in one of his famous sweepings of the heavens. It is nineteen times as far from the Sun as the Earth, its diameter is four times the Earth's, and, traveling four miles per second, it requires eighty-four years to complete the circuit of the Sun. It has four known satellites.

The discovery of the next planet, *Neptune*, was, as you know, a great event in the history of astronomy. *Uranus* did not follow precisely the path marked out for it by astronomers, and Adams of Cambridge in 1845, and Leverrier of Paris independently a year later, proved that the discrepancies in its motion could be caused by the attractions of an undiscovered planet farther from the Sun than itself. They computed the position of the undiscovered planet. Adams tried to enlist the services of the greatest telescopes in England to discover the body, but his advice and requests were neglected. It is especially appropriate in these days of war between the nations to note this illustration of the international character of astronomical research: Leverrier of Paris requested Astronomer Galle of Berlin to search for the new planet, with the largest telescope on the continent. Galle found the planet on the first night of the search, almost exactly where Leverrier said it would be. *Neptune* is a little over four times the Earth in diameter, and he requires 165 years to travel through his orbit. He has gone less than half way around the Sun since his discovery. *Neptune* has one known moon.

It is not impossible that other planets more distant than *Neptune* are revolving around the Sun. Several astronomers have devoted much time to searching for them.

The Earth-Moon system is a unique combination, in that the two bodies are more nearly of the same size than are any other planet and its satellites. The Moon's diameter is considerably over a fourth of the Earth's diameter. It required the Washington 26-inch telescope to discover the two tiny moons of *Mars*, but an astronomer on *Mars* or on *Venus*, when those planets are in favorable positions, would not need any telescope at all to see the Earth and its Moon as a double planet—the only double planet, so to speak, in the solar system.

It is a most remarkable fact that all of the eight major planets and all of the more than 800 asteroids revolve around the Sun in the same direction, which astronomers have agreed to call from west to east. There is no exception to this rule. It is an equally remarkable fact that the eight planets revolve in orbits lying nearly in the same plane, and that the average position of the orbital planes of the 800 asteroids coincides closely with the average for the eight planets. Let us refer the planes of the orbits of the planets and asteroids to what we may call the average plane of the planets' orbits. *Mercury's* orbit is inclined six degrees to the average plane, and *Venus's* orbit two degrees. The orbit planes of the other five planets are inclined, without exception, less than two degrees to the average plane of the system. The orbit planes of a few of the little asteroids are inclined as much as thirty or forty degrees to the plane of the system, but the great majority of the asteroids do not get far from that plane.

Other striking and related facts are these: The Sun rotates on his axis from west to east. We do not positively know the directions of rotation for *Mercury* and *Venus*, but there are reasons for thinking that their direction is also from west to east. Our Moon revolves around the Earth from west to east, and the Earth and Moon both rotate on their axes from west to east. *Mars* rotates from west to east, and his two moons revolve around the planet from west to East. *Jupiter* and *Saturn* rotate on their axes from west to east, but in the satellite systems of these planets and in the systems of *Uranus* and *Neptune* we come upon exceptions to the west-to-east rule. The seven inner satellites of *Jupiter* revolve from west to east, but the eighth and ninth satellites, which are farther out from the planet than the other seven, travel from east to west. The eight inner satellites of *Saturn* travel from west to east, but the far-out ninth reverses the direction. The four moons of *Uranus* revolve around that planet in a plane which is nearly at right angles to the average plane of the planets, and the plane of the satellites of *Uranus* is probably the approximate plane of the equator of that planet. The satellite of *Neptune* revolves around its planet from east to west in a plane inclined at an angle of thirty-five degrees with the plane of the planets. We should note that the exceptional cases refer to the outermost planets of the solar system, *Uranus* and *Neptune*, and to the outermost satellites in the systems of *Jupiter* and *Saturn*. Everywhere else in the solar system prevails the rule of motions of revolution and rotation from west to east.

The solar system, of great extent in the plane of the system, is an exceedingly thin system. Let us call the distance from the Sun to the Earth one; then the distance from the Sun to the outermost planet, *Neptune*, on the same scale is thirty, and the diameter of *Neptune's* orbit is sixty. Now our system of Sun, planets, satellites and asteroids lies so nearly in one plane that we could put it in a very flat bandbox, sixty units in diameter and one unit in thickness, so that the major planets and their satellites, and all the asteroids, with a very few exceptions, would perform their motions entirely within the box. The exceptional asteroids and the majority of the comets would dip out of the box on one side or the other because the planes of their orbits make considerable angles with the central plane of the solar system.

I want to call your attention as forcibly as possible to the extreme isolation of our system from other systems. If it is one unit of distance from the Sun to the Earth and thirty units from the Sun to the outermost of our planets, *Neptune,* it is, on the same scale 275,000 units to the nearest star of which we have any knowledge, *Alpha Centauri.* It is about 400,000 units in an entirely different direction to our second nearest neighbor, and so on. Most of the comets and some of the meteors, as we shall learn in the next lecture, travel out much farther from the Sun than *Neptune* is; but, aside from some of the comets and meteors, we do not know that there is anything in space between *Neptune*, thirty units from the Sun, and the nearest star, several hundred thousand units from the Sun.

Let us illustrate our isolation in still another way. Light travels from the Sun to the Earth in eight and one-third minutes, and from the Sun to *Neptune* in four and a half hours; but it requires four and a half years to travel from our Sun to the next nearest star, *Alpha Centauri.* The distance of *Alpha Centauri* is described as four and a half light-years. The average distances between the stars are six or seven or eight light-years.

It must be clear that the stars and the planets occupy little space, and that they have a superabundance of room to move about. We have found that the average speed of the naked-eye stars in their motions thru space is about sixteen miles per second, which means that if one star should start to travel precisely toward its nearest neighbor, assuming its nearest neighbor to be at the average distance, it would require some eighty thousand years to arrive at its destination. Now the diameter of our Sun, an average star, is not more than one fifty-millionth as great as the average distance between neighboring stars. Under such conditions it is not difficult to see that a collision of two stars must be an exceedingly rare event. The approach of two stars so close as to disturb each other violently must also be rare. However, when we consider the number of stars in the stellar system, we should perhaps expect a few close approaches to occur within a human lifetime.

The researches of the early astronomers were confined almost exclusively to the solar system. Their small and imperfect telescopes lacked the power, and their methods lacked the accuracy for attacking the problem of the distant stars. They made a specialty of the motions of the bodies which compose the solar system, of their forms and dimensions, and of their orbits. Their labors, supplemented by that of astronomers still living, have been so thoro and complete that we can predict the motions of the planets around the Sun and the motions of the satellites around the planets with very great accuracy. It would be possible to compute the point in the sky which the planet *Jupiter* will occupy one hundred years from this evening, and the telescope could this year be directed to that point so accurately that, on looking thru the telescope one hundred years from tonight when the clock said the precise second had arrived, the planet would be seen very close to the center of the telescopic field of view. The eclipses of the Sun are computed so accurately that the astronomer may, if he chooses, go years in advance to the proper point for observing a given eclipse and direct his telescope so precisely to the position which the eclipsed Sun will occupy as to witness the phenomenon when it arrives, without more than a minute change in the pointing of his instrument. The pointing of the instrument would probably not be exactly right, because the Moon deviates a little from the path laid down for it; astronomers do not know why. It has, in fact, been suggested that the Moon's motion may be affected slightly by some force or forces whose nature has not yet been determined. There is likewise an appreciable discrepancy in the motion of *Mercury*. Whether this discrepancy will ever be removed by virtue of a more complete application of Newton's law of gravitation to the problem is uncertain; some other force than gravitation may be acting, but it need be only a very minute force.

The zodiacal light, a faint illumination of the sky visible above the Sun when the Sun is a few degrees below the horizon, is an interesting phenomenon surrounding the Sun. There is no reason to doubt that the zodiacal light which we see comes originally from the Sun, and that this light falls upon and is scattered by finely divided material—dust grains or very small bodies in great numbers which revolve around the Sun, each such particle in effect a little planet. This material is distributed thru a great volume of space, somewhat in the shape of a double-convex lens whose center coincides with the Sun and whose edge extends out even farther than the Earth's orbit. Its shorter dimension extends so far to the north and to the south of the Sun that northern observers, well situated, may see the zodiacal light at midnight in May, June and July above the northern horizon.

Belonging to the solar system also are the comets, which pass around the Sun in orbits for the most part very elongated. We shall study the comets in the next lecture.

There are the meteors, many of which revolve around the Sun in orbits which mark them as members of the Sun's system. It is probable that some of the meteors are merely passing thru the Sun's system and are not of it. Occasionally a meteorite gets down thru our atmosphere to the Earth's surface, is found, and is installed in a museum; but many millions which collide with our atmosphere every twenty-four hours are consumed by the friction of the Earth's atmosphere and lose their identities.

The distribution of the material in the solar system is most remarkable. Nearly all of it is in the Sun. If we add together the masses of the major planets, their satellites, the hundreds of asteroids, make liberal allowance for the masses of the comets, meteors and zodiacal-light materials, and call the total one, then the mass of the Sun on the same scale is 744; that is, of 745 parts of matter composing our solar system 744 parts are in the Sun and only one part is in the bodies revolving around it. To state this in another way: ninety-nine and six-sevenths per cent. of the material of the solar system is in the Sun, and only one-seventh of one per cent. is divided up to make the planets, satellites, asteroids, etc. The four outer planets, *Jupiter*, *Saturn*, *Uranus* and *Neptune*, contain 225 times as much material as the four inner planets, *Mercury*, *Venus*, *Earth* and *Mars*. The Earth is fully 3,000 times as massive as the more than 800 asteroids combined. It is not known how much material is responsible for the zodiacal light. The more finely divided that material is, the smaller is the total mass required to reflect and scatter the quantity of solar light observed in that phenomenon. Seeliger has thought that the scattered zodiacal light materials, if condensed into one body, might have a mass fairly comparable to that of the little planet *Mercury*, and he has concluded that the attractions of the zodiacal light materials upon the planet *Mercury* could explain the deviations of that planet from its computed orbit. This problem cannot yet be regarded as definitely settled. For several decades astronomers thought there might exist an undiscovered planet or planets of considerable size between the Sun and the orbit of *Mercury* whose attractions upon *Mercury* were responsible for the discrepancies in its motion. The work of the Crocker eclipse expeditions from the University of California is morally conclusive that there are no such planets massive enough to explain the observed discrepancies. We do not know the mass of any single comet, but we do know that cometary masses are exceedingly small in comparison with the masses of the smallest planets. The recent comets which have approached close to *Mars*, *Earth*, *Mercury* or *Venus* have produced no appreciable disturbances in the motions of those planets.

We have described the known members of the solar system as to dimensions, masses, orbits and geometrical relations and situations one to another. We have seen that they form the Sun's system—a system very completely isolated in space, and independent of other systems so far as its internal relations are concerned. Now the solar system as a whole is traveling thru space with reference to the other members of the stellar system. Sir William Herschel suggested, a century and a third ago, that the apparent motions of the other stars were such as to indicate a motion of our star and its system toward the constellation *Hercules*, and this conclusion has been amply verified by Herschel's successors. The logic of the demonstration is very simple. Let us use an illustration which every one has had or may have the opportunity to test. Suppose the observer is traveling rapidly by railway train across a level tract of country, say toward the west. He will notice that the trees, buildings, or other objects on his western horizon appear to separate gradually. Similar observations on the trees and other objects on the eastern horizon will show that they appear to approach each other. The trees and buildings on the horizon to the right and to the left of him will seem to be traveling toward the east. The explanation is apparent. The motion of the solar system thru space is a much more complicated problem, in that we must deal with space of three dimensions, instead of the two dimensions of the terrestrial surface, and the stellar objects which the observer sees in all directions from him are themselves in motion. However, if the positions of a great number of stars have been accurately determined at some past epoch, as was indeed the case, and the recent determinations of positions of the same stars be compared with the early positions, it will be found that the stars have moved. They will have moved with a great variety of speeds in a great variety of directions; but if the stellar motions are studied with care, it will be found that the prevailing motion of any great group of stars in any large area of the sky will be away from the region of the the constellation *Hercules* and toward the opposite point of the sky. Herschel reasoned truly that this prevailing drift of the stars away from the constellation *Hercules* was due to the motion of the solar system, year after year, decade after decade, toward that constellation. Modern solutions of the same problem have changed the estimated position of the Sun's goal very slightly toward the southeast, to a point near the boundary line between the constellations *Hercules* and *Lyra*. Astronomers did not succeed in determining the speed of the solar motion from these apparent motions of the stars. The difficulty lay in the fact that we did not know the distances of the stars whose angular motions had been observed. The spectrograph has enabled the second part of the problem to reach a satisfactory solution. This wonderful instrument enables us to measure the motions of approach and recession of the stars, and this has been done for 2,000 or more of the stars, chiefly under the auspices of the University of California, by the Lick Observatory for the northern stars, and by the D. O. Mills Expedition to Santiago, Chile, for the southern stars. It has been found that the stars have a great variety of motions of approach and recession. If we examine the results for a hundred neighboring stars in some one large area of the sky, we shall find that a few will be approaching the solar system at high speed, others will be receding from our system at high speed, and the others will be represented by a great variety of motions of approach and recession. This happens for great groups of stars in any part of the sky. If we consider the observed motions of 100 stars in and surrounding the constellations *Hercules* and *Lyra*, we shall find the same variety of speeds, but if we take the average speed of the group we shall find that the group as a whole seems to be approaching us at the rate of about twelve and a quarter miles per second. In a similar manner, if we consider the motions of 100 neighboring stars in precisely the opposite region of the sky, we shall find the same variety of approach and recession, but we shall obtain for the average speed of the 100 stars as a group an apparent recession of about twelve and a quarter miles per second. No one questions the explanation of these observed facts, that the solar system is traveling toward the *Hercules-Lyra* region with a speed of about twelve and a quarter miles per second with reference to the system of naked-eye stars. Now this speed of motion is carrying the solar system thru space at the rate of approximately 400 million miles per year. There are the best of reasons for believing that our solar system is very old. Its age can scarcely be less than many tens of millions of years, and more probably hundreds and thousands of millions. It is clear that the youth of the solar system was spent in a very different part of the stellar system from where it now is, and that its old age will be lived in a still different region. We do not know whether the motion of the solar system follows a straight line, or a closed curve such as an ellipse, but the system is probably obeying the gravitational attraction of the rest of the material universe. It seems probable that the orbit is a great ellipse, whose circuit is so great that many hundreds of millions of years will be required to travel over it once, even tho our system meet with no disturbing element in the meantime.

It will be profitable to consider briefly the conditions existing in the Sun and planets. Geologists have been able to study in a limited way the outcropping geologic strata of the Earth, but all of these strata combined are only a few miles in thickness. There are indirect ways of studying the interior of the Earth, and essentially every modern student of the subject has come to the conclusion that the interior of the Earth is solid thruout, with the possible exception of relatively small pockets of molten matter here and there. We know something about the oceans and the atmosphere of the Earth. Do any of the other planets resemble the Earth? *Mercury*, *Venus* and *Mars* certainly have some resemblances to our planet, but the giant planets *Jupiter*, *Saturn*, *Uranus* and *Neptune* are extremely unlike the Earth. The Earth appears to be the densest of all the planets, tho considerable uncertainty exists as to the density of *Mercury*. *Venus* is about nine-tenths as dense as the Earth, and *Mars* is about seven-tenths. The four great planets average about one-fifth the density of the Earth. *Jupiter*, *Uranus* and *Neptune* are a little more dense than water, whereas *Saturn* is so light that if it could be thrown upon a great terrestrial ocean it would float like a piece of wood.

We can get no trace of an atmosphere on *Mercury*, and much remains to be done in the way of investigating the atmosphere of *Venus*. The later planet certainly has an atmosphere, but whether it is comparable in quantity and chemical composition with the Earth's atmosphere we do not know. As *Venus* is only a shade smaller than the Earth, we should expect the atmosphere of the two planets to be not very unequal. We know that *Mars* has an atmosphere, but it is a very light one. The Martian atmosphere at the surface of that planet is probably not over one-half the density of the Earth's atmosphere at the summit of Mount Everest, our highest mountain peak. There is no reason to doubt that the composition of the Martian atmosphere is very much like our own. A great white area around the north pole of *Mars* waxes and wanes with the coming and going of winter in the northern hemisphere of Mars, and a similar white cap comes and goes at the south pole of the planet. These are just such phenomena as occur every year on the Earth. If we were transported a few thousand miles above the northern hemisphere of the Earth, we should see a great white cap growing in the fall and winter from the Arctic regions southward across Europe and Asia to the latitudes of the Mediterranean Sea and the Himalaya Mountains, and across Canada and the United States well toward the Gulf of Mexico; and we should see the southern edge of this cap retreating northward with the advent of spring and summer. An observer over the southern hemisphere of the Earth would witness the annual waxing and waning of the white cap around the south pole of the Earth, save as the southern oceans interrupted its continuous progress.

The four giant planets have enormously extensive atmospheres. We appear to be able to see at all times clouded areas of tremendous extent. These clouds are more prominent in *Jupiter* than in *Saturn, Uranus* and *Neptune*, but that the surfaces of all four have a very high percentage of clouds we can scarcely doubt. The immense masses of material in these planets and their low average densities lead us unavoidably to conclude that they are not solid, as in the case of the Earth, but that they are largely, and perhaps entirely, in a gaseous state, except as the enormous interior pressures, due to the overlying strata, may liquify or even solidify their central volumes. It is thought that the gaseous strata in each of the four planets extend to great depths and that there is nothing in the nature of a solid or permanent crust over the surface of any of them. Their low densities probably mean that their enormously deep atmospheres are still quite hot. Yet we have no evidence that any one of them is shining by its own light. When one of *Jupiter's* large satellites passes between the Sun and the planet, eclipsing a small area of the planet's surface, that area appears to be absolutely dark.

We should call attention to the flattened forms of *Jupiter* and *Saturn*. The rotation of the Earth once in about twenty-four hours has caused the equatorial regions to be thrown out by centrifugal force, in effect, and the polar regions to be correspondingly drawn in, until the difference between the equatorial and polar diameters is twenty-six miles. The great planet *Jupiter* rotates on its axis in a little less than ten hours, whereas the little Earth takes twenty-four hours. A point on *Jupiter's* surface is traveling by rotation some twenty-seven times as rapidly as a corresponding point on the Earth's surface. The centrifugal force is enormous, and the result is easily observable in the equatorial and polar diameters, for there is a difference of about 5,000 miles. The effect is even larger in the case of *Saturn*, where the difference of the diameters is nearly 7,000 miles. The throwing of the clouds in the atmospheres of these two planets into belts parallel to the equators is undoubtedly connected with the extremely rapid rotations of the planets, probably thru the medium of trade winds blowing nearly parallel to their equators. If our Earth rotated more and more rapidly our trade winds would approach more and more to parallelism with the equator.

The rings of *Saturn* are unique in the solar system. Maxwell of England proved by mathematics, and Keeler of America proved with the spectroscope, that these rings are a great collection of minute and separate bodies. There are so many of these particles or separate masses that they seem to form a continuous and solid system, except as we see the dark lines dividing them into several component rings. If the rings were solid like a wagon wheel, to use a homely illustration, the outer edge would travel by rotation more rapidly than the inner edge. The spectrograph has shown that the reverse is the case. A moon at the inner edge of the ring system would have to travel very rapidly to save itself from falling upon the planet. A moon at the outer edge of the ring would travel much more slowly. Keeler proved that each point of the ring system is traveling with the speed which a moon at that distance from the center of the planet would have. Each point in the ring system is a separate moon revolving in an essentially circular orbit about the planet, and in harmony with the gravitational power of the planet.

Our Moon, as you know, is apparently without atmosphere and water, tho it should be said that one astronomer thinks he has observed changes in the bottoms of the lunar craters, such as to suggest the presence of a trace of water in the form of frost. These observations should be verified before they are interpreted on the basis of water vapor. The verification has not yet been provided.

Most interesting of all the bodies in the solar system is the Sun itself. It is an intensely hot sphere whose outer strata, certainly, are gaseous. The gaseous composition may indeed extend from surface to center; but it is much more probable that the great central volume is in the liquid or even solid state, owing to the tremendous pressures which exist there. We know that the surface temperature of the Sun is in effect as high as 10,000° Fahrenheit. The interior temperatures must be vastly higher. The chemical elements known to us could exist at such temperatures only in the form of incandescent gases or vapors, except as immense pressure condenses them to the liquid or solid state. We know that our atmosphere and hydrogen and the other gaseous elements of the Earth can be liquefied and solidified by means of such pressures as our laboratory methods are able to produce. The pressures in the depths of the Sun run up into the millions of pounds per square inch; and, while the temperatures there existing undoubtedly try to preserve the gaseous state of the Sun's interior, the stupendous pressure probably conquers the expansive forces and reduces the central mass to the liquid or solid state. It is scarcely possible that a liquid or solid core extends from the center out to near the surface of the Sun, for the average density of the entire body is only 1.4 times the density of water.

About forty elements familiar to us on the Earth have been shown to exist in the outer strata of the Sun by means of the spectroscope. Rowland has said that if the Earth were heated up until its temperature is equal to that of the Sun, the Earth's spectrum would probably resemble closely the spectrum of the Sun.

When we look at the Sun we see what we call the photosphere. The prevailing opinion of the photosphere is that it consists of clouds produced by the condensation of some of the vapors, formed in the atmosphere of the Sun when the conditions for condensation are right, very much as our own clouds form in our atmosphere when the conditions are right. The clouds of water vapor with which we are familiar form at a low temperature because we are dealing with water which has a freezing temperature of +32° Fahrenheit. Clouds would be expected to form from iron vapor at a very high temperature, for the freezing point of iron is about 1500° above zero Fahrenheit.

The atmosphere of the Sun is in rapid circulation. There are great storms in its atmosphere, vastly more violent than those in the Earth's atmosphere. In terrestrial storms there are great whirling disturbances in our atmosphere. The sun-spots are to us the outward and visible sign of somewhat similar storms, on a tremendous scale. The motions of gases and vapors in sun-spots have been measured by means of the spectroscope, and Hale has shown that sun-spots are the centers of local magnetic fields. The magnetic field is probably developed in each case by the rapid rotation of electrically charged particles within the volume of spot disturbance.

The sun-spots, as well as other details of the Sun's surface, reveal a curious law of solar rotation. The entire Sun is rotating rapidly from west to east, but the equatorial regions are rotating more rapidly than the regions of high latitude. Areas near the equator rotate once around in twenty-four days, but at forty-five degrees of north and south latitude the rotation period is twenty-eight days, and at seventy-five degrees of north and south latitude the period is thirty-three days. The forging ahead of the equatorial regions has never been satisfactorily explained.

The sun-spots vary in size most curiously, and for reasons unknown. The spottedness passes from minimum to maximum and back again to minimum in an average period of eleven and one-tenth years. During the years of minimum it is not unusual for the spots to be entirely absent for weeks at a time. The full line curve which represents the spottedness of the Sun as observed from the year 1740 up to 1870 shows that twelve maxima and twelve minima occurred in this interval. The maxima and minima do not come with perfect regularity. Sometimes the maximum is a year or two early, or a year or two late, and similarly for the minima. Many investigators have tried to find an explanation of the sun-spot period, but the results have not been satisfactory. The cause has been looked for in the action of the planets. It would seem that if any of the planets is responsible it should be the giant *Jupiter*. There is no apparent connection, for *Jupiter's* period about the Sun is 11.9 years, whereas the sun-spot period is 11.1 years. It has been suggested that the spots are formed when two or more of our planets are in the same straight line with the Sun, but the fact is that there are just as many spots visible when the planets are equably distributed around the Sun, with no two of them in or near a straight line with the Sun. The cause of periodicity seems to lie within the Sun itself. It is perhaps not impossible that certain forces develop and accumulate within the Sun until they reach the breaking-out intensity, once in eleven years, somewhat after the fashion of the forces which are responsible for the geysers on the Earth. I do not mean to convey the impression that the motions within sun-spots and the motions of water expelled from geysers are the same, as they are not. Experienced investigators have tried to find a relationship between sun-spots and terrestrial weather, but they have not succeeded in proving that such is the case. There have been and still are people who say that the sun-spots rule our weather, but they seem not to know what constitutes a scientific proof; at least, no proof has been published. They remind me of the small boy's first experience with an electric trolley car. The street-cars in his town had been drawn by horses, and he had no doubt as to the motive power. There came a morning when he and his father got on a successor to the horse-car, and he was interested to know what made the car go. His father tried to explain that it was electricity, but the boy was not convinced, and this is not surprising, for nobody even now knows what electricity is. Before he got to the end of his trolley ride he said, "Father, I have discovered what makes this car go. It is that bell up there above the driver's head, for I have noticed that every time that bell rings the car starts." Therefore, according to the same logic, as there are spots on the Sun and there are rain storms on the Earth, the sun-spots cause the rain. Unfortunately it happens, now and then, that we have an exceedingly dry winter month when the Sun is rich in spots, and a wet month had been prophesied; and that we have an exceedingly wet winter month, now and then, when no spots whatever are visible. It rains no more in the three or four years of sun-spot maximum than it does in the three of four years of sun-spot minimum. Likewise, the storms are no more numerous and no more severe when there are two or three planets almost exactly in line with the Sun than when the planets are equably distributed around the Sun.

In one respect we are sure that the sun-spots do have a terrestrial influence. Magnetic disturbances on the Earth are directly related, in some way, to the sun-spot activity. The curve of magnetic disturbances when correlated with the curve of solar spottedness, shows an agreement that is unmistakable.

Outside and beyond the spherical body of the Sun which we see every clear day are the prominences and the corona. The prominences are certainly connected with, or are the fruits of, the circulatory system of the Sun's atmosphere. They require special spectroscopic apparatus for their observation in ordinary times, but they can be seen directly at times of solar eclipses, when the main body of the Sun is hidden behind the Moon and the background of sky is relatively dark. They are of great variety as to forms and speeds of development. They sometimes shoot up to heights of two or three hundred thousand miles above the Sun's surface, with speeds as high as 250 miles per second.

The solar corona may also be a product of the rapid circulation within the Sun's structure. It is not impossible that the materials composing the corona are expelled from the Sun by something in the nature of volcanic force, or by the pressure of the intense solar rays upon the minute particles of the corona, or by other force or forces, and that these particles find their way back in descending streams to the Sun. The corona is a part of the Sun. A complete understanding of our Sun requires a study of the corona, and it is chiefly for investigations of this solar appendage that eclipse expeditions are dispatched to the out-of-the-way corners of the Earth. It has been found that the form of the corona depends upon the spottedness of the Sun. At times of spot maximum the corona is nearly circular in general outline, whereas at times of minimum the coronal streamers which extend out from regions of low latitude are extremely long, and the streamers which originate at high latitudes and in the vicinity of the poles of the Sun are very short.

People in general know that the Sun is vital to life on the Earth, but they do not realize that all other sources of energy are negligible. The Sun's light and heat grow the farmers' crops. The solar radiation grows the forests of today. It grew, long ages ago, the luxuriant vegetation which, submerged and compressed, is the coal that today drives the railway trains of the land and the ships of the sea. It is the Sun's power which evaporates the water of the ocean and creates the winds which carry the evaporated water over the mountains where it is deposited as rain and snow. Our hydro-electric plants control the descent of this water from the mountains to the sea, and their water-wheels and dynamos generate electric current. The Sun's energy thus transformed illuminates our cities and drives the trolley cars. We do not depend at all upon the Earth's internal heat. The temperature of the Earth's surface is determined by the heat received from the Sun. To realize this fact, let us recall the frigid conditions perpetually existing at the poles of the

Earth. During several weeks in the middle of the northern summer the north pole receives more solar heat than any other region of the Earth, and thruout the year some of the heat from the tropics and the north temperate zone is constantly transmitted by atmospheric circulation to the north polar region. Similarly, during several weeks in the middle of the southern summer the south pole of the Earth receives more heat than any other region of the Earth, and constantly thruout the year some of the heat of the tropics and of the south temperate zone is conveyed thru the atmosphere to the region of the south pole. Yet how frigid and essentially useless in the vegetable and animal world are the polar regions! The interior heat of the Earth is not able to do anything appreciable for those regions. Now if the Sun's heat were cut off completely from the Earth for one short month, the equatorial regions would be at the end of the month so wintry that the north and south polar regions as they are today are rose gardens in comparison.

To create due respect in our minds for the overwhelming power of the Sun, we may reflect upon the following statement: When the Sun is directly or approximately over any region of the Earth and our atmosphere above that region is in normally clear condition, each square yard of that region receives energy from the Sun's rays at the approximate rate of four-fifths of one horsepower. This is at the rate of 4,000 horsepower per acre. If you own 250 acres of desert in Arizona, or Mexico, or northern Africa, the Sun in the middle of each summer day is pouring down energy upon your little ranch at the rate of one million horsepower. Your neighbor's ranch of the same size is receiving solar energy at the same rate. And so on for the entire surface of the Earth, in proportion as the Sun's rays fall perpendicularly or slantingly upon each area. Yet this is far from the whole story. Nearly the half of the energy which the Sun tries to send to the Earth's surface is intercepted by our atmosphere and turned back into space. With the Sun directly overhead for the various regions of the Earth, only about sixty per cent. of the Sun's energy gets down thru the atmosphere to the land and water surface of the Earth, and the remainder is refused transmission. Now the Sun, to the best of our knowledge, is sending out energy in all directions at essentially the same rate. The little Earth covers so small an area of the sky, as one would see the sky if he were on the Sun, that the Earth intercepts only one two-billionth part of the Sun's radiation. If we could cover the Sun with a shell of ice forty feet thick, the heat energy radiated from the Sun, at its present rate, would be sufficient to melt that shell of ice in one minute of time. To produce this quantity of energy from the combustion of coal would require that a layer of the best anthracite twelve or fifteen feet deep over the entire solar surface be consumed every hour. Now, if the Sun were composed of anthracite the consumption of the whole mass would not furnish sufficient heat to supply the Sun's output, at the present rate, for as long as 10,000 years. It was Kant in the eighteenth century, and Helmholtz independently a hundred years later, who showed that the contraction of the Sun under the influence of its own gravitational power is the most probable explanation of its source of heat; perhaps not its sole source, but a source which would suffice to maintain the present rate of radiation for many millions of years. The Sun's own gravitational power is struggling constantly to draw every one of its particles to the center of the Sun; it is subjected to its own immense compressive force. Now we know that when we compress air, for the purposes of industry or to fill an automobile tire, a great quantity of heat in the air compressed is liberated and radiated into surrounding space. In the same way the constant and stupendous process of compression which the Sun suffers from its own internal gravitation liberates the heat that is latent within its mass. The immense quantity of energy represented by the actual motion of the Sun's materials inward toward the center is also converted into heat. These are such fruitful sources of heat that the Sun need contract no more than 300 feet per year at the present time to supply the radiation which goes out in all directions and of which a very little reaches us upon the Earth. This is so slow a rate of solar contraction that we could not hope to observe any diminution in the Sun's diameter, even with the most refined measuring apparatus, until after the passing of some 5,000 years. There can be no doubt that this solar compression will liberate sufficient heat to maintain the present rate of flow for five or ten millions of years, and it can be shown by the application of the same principles that the Sun may well have been radiating heat at an approximately equal rate for five or ten millions of years in the past. It is essentially certain that the radium within the Earth is a powerful factor in developing the Earth's internal heat. We have no evidence as to the existence of radium in the Sun, but it or some of its radio-active relations may be there to assist in giving long life to the Sun and to the planets which draw their sustenance from the Sun.

What can be said as to the existence of life on the other bodies of the solar system? We may dismiss the Sun as too hot to support any form of life with which we are acquainted. Our Moon cannot support life, at least of the terrestrial kinds, because of the total lack of air and water. The probabilities are strong the *Mercury* is lifeless, for the same reason, but this is not a certainty. I think we may dismiss *Jupiter*, *Saturn*, *Uranus* and *Neptune* as abodes of life: we do not see how they can have anything in the nature of solid surfaces. *Venus* and *Mars* are the planets most nearly equal in size to the Earth. *Mars* has a very light atmosphere, certainly, but we know nothing as to the extent of *Venus's* atmosphere, except that it has one. If Schiaparelli was right in his conclusion that the planet *Venus* always presents the same face to the Sun, as it probably does, then life on *Venus* would be difficult: one hemisphere would have eternal day with burning temperatures, and the other hemisphere eternal night with extreme cold. *Mars* and the Earth seem to have many resemblances. Seasonal changes occur on *Mars* such as could reasonably be attributed to changes in vegetation; and if there is vegetable life there could well be, and probably is, animal life. However, the vegetable may be easily independent of the animal; the forests and prairies of the Mississippi Valley put on their green clothing in the spring of every year and changed to brown clothing in the fall of every year even better before the coming of "intelligent" man than after his appearance on the scene. The "canals" of *Mars* may be evidence of intelligent life on that planet; but unless we accompany them with some rather violent assumptions the canals could serve equally well as examples of the lack of intelligence on the planet. How would engineers on the Earth proceed to catch the water from the melting north polar cap of the Earth and use it for irrigation, not only south to the equator, but well down into the southern hemisphere? How would they reverse the process and use the waters from the south polar cap to irrigate not only as far north as the equator but well into the northern hemisphere—it being assumed that there are no oceans to interfere? Would intelligent engineers insist on running their canals absolutely straight for thousands of miles, or would they follow the contours? As the surfaces of the Earth and the Moon are exceedingly unlevel, is it reasonable to assume that *Mars,* half way between the Earth and Moon in size, has a level surface? *Mars* probably has animal life, but in my opinion we have not the proof of it.

I think it is impossible for an intelligent and thoughtful mind to contemplate the orderly solar system, completely isolated from other systems, its great Sun in the center, the tiny planets and the infinitesimal asteroids revolving around the Sun in the same direction and nearly in a common plane, the moons revolving around the planets, all of the planets and asteroids around the Sun from west to east, and nearly all of their moons around their planets from west to east, without saying to ourselves: the members of the solar system have had a common origin; the materials in the Sun, the planets and moons have had a prior existence under other conditions; and the operation of the laws of nature has developed the system to its present state, and will guide its further development to the state which the future has in store for it. Kant's hypothesis would have the development proceed from a great collection of matter in a chaotic state—the same matter which, transformed and redistributed, now composes the system. LaPlace's hypothesis would develop the solar system from a rotating parent nebula. Chamberlin would have the antecedent nebula spiral in structure. This phase of the subject would demand a full hour for adequate treatment, and we must be content to say that all astronomers believe the solar system to be the product of evolution.

Are there other solar systems than ours? Are there planets revolving around the other stars, as our planets revolve around our Sun? Is there life on planets in other systems? We do not know. We are powerless to answer these questions at present. If we should transport our astronomers and their most powerful instruments to *Alpha Centauri,* the solar system's nearest neighbor, they could not look back and see the planets which attend our Sun. They would see our Sun by naked eye as a first magnitude star, but our greatest planet, *Jupiter,* would be a star of the twenty-first magnitude, and their telescopes at *Alpha Centauri* would have to be at least twenty-five feet in diameter in order to show *Jupiter* as a stellar point of light, just on the limit of vision, even tho the flood of light from our Sun did not interfere with the observation. The fact is that *Jupiter,* as seen from *Alpha Centauri,* would never be more than five seconds of arc from our Sun, and the glare of sunlight in the Centauran telescope would hopelessly drown the image of *Jupiter,* even tho the diameter of the telescope were much greater than twenty-five feet. The latter difficulty would resemble that of trying to see a glow worm that is two feet to the right or left of a powerful searchlight located sixteen miles from the observer.

Altho we have not been able to secure direct and positive evidence in favor of other planetary systems, and altho we see no promise of such evidence in the future, it would be unreasonable to believe that such planetary systems do not exist. It would be contrary to the simple probabilities if our Sun, one of several hundred millions of suns, were the only Sun attended by planets, and our Earth were the only planet that is the abode of life. We are not able to prove that we have neighbors scattered thruout the great stellar universe, but we are justified, I think, in believing that they are there.

THE TOTAL SOLAR ECLIPSE OF FEBRUARY 3, 1916.

By C. D. Perrine.

The total solar eclipse of February 3, 1916, was observed at Tucacas, Venezuela, by an expedition from the Observatorio Nacional Argentino in charge of Third Astronomer Chaudet.

Owing to the general financial depression resulting from the great European war, it was not possible to send so well equipped an expedition as those which went to Brazil in 1912 and to Russia in 1914. This was unfortunate, particularly in the matter of the large-scale photographs of the corona. To have sent our 40-foot camera would have been to endanger the success of the entire expedition, and it was therefore with great reluctance that plans had to be made without it. Dependence for that part of the program had to be placed upon a camera of 11 feet focus attached to one of the polar axes.

It was also necessary to omit observations of the polarized light in the corona with the 11-foot cameras which were part of the equipment sent to Brazil and Russia.

The program of observations comprised the following:

A. Photographs of the corona with a camera of 11 feet focal length.

B. Photographs of the corona with a camera of 6 feet focal length.

C. Photographs of the flash spectrum and of the spectrum of the corona with an objective prism spectrograph of 5 inches aperture and 6 feet focal length.

D. A program similar to C with a prismatic camera of 27 inches focal length.

E. Photographic observation of the general spectrum of the corona with a slit spectrograph.

F. Photographic determinations of the total amount of light from the corona.

G. Visual determinations of the times of the contacts.

It was impossible to obtain some kinds of plates and films which in normal times are always to be had. This was a serious handicap chiefly to the spectroscopic and photometric work. No fresh orthochromatic or panchromatic plates could be found.

The expedition left Córdoba on December 2 and arrived in Tucacas on January 14 after many difficulties in obtaining transportation from Barbados to the Venezuelan coast.

The first week at Tucacas was rainy and unsuitable for the work of setting up the instruments, but by hard work Mr. Chaudet, without assistance except for a very little common labor, succeeded in getting all of the six instruments in condition for observing. These were mounted on two polar axes.

Efficient and willing assistance for making the observations was offered freely, and an able corps of observers was trained for a week before the eclipse.

The morning of the eclipse dawned rather unpropitious with heavy rain. Conditions improved, however, and by the time of totality the sky was covered only by thin haze. The haze interfered to some extent with the observations, chiefly those of the extensions and the general spectrum of the corona. It interfered much more seriously with the naked-eye view.

The entire program was carried thru as planned, and the plates developed on the four nights following. Twenty plates with twenty-eight exposures were obtained.

The focus of the 11-foot camera and of the large prismatic camera were excellent. There were some very small vibrations to the 11-foot camera, which disturbed the short exposures and the images of the prominences to some extent. They were not sufficient, however, to interfere greatly with the corona, especially the longer exposures.

The images with the 6-foot camera and the small prismatic camera are not sharp. Some of this is probably due to the diffusion by the clouds, but it is feared that some disturbance of focus of the 6-foot camera occurred, altho no such disturbance was noted after the eclipse, nor can any be accounted for. The focal image was examined visually shortly before totality and was then excellent.

The lack of sharpness is not sufficient to render these negatives entirely useless by any means, for the general features of the corona and the streamers are well enough shown for some purposes, as are also the prominences. In the small prismatic negatives the general forms of the images are easily distinguishable and many of the lines well enough separated and sufficiently sharp-edged for measurement.

The exposures with the large prismatic camera were all made on flat plates. The focus from the extreme red end ($\lambda 7300\pm$) to about H and K is good. Above H and K it is not sharp, altho many lines can undoubtedly be measured with some accuracy owing to the large scale.

Standard intensity squares were impressed on the long exposure of the 11-foot camera and the photometric plates before leaving Córdoba and these were then hermetically sealed in tin (as were all of the plates to be used on eclipse day). These were not opened in Tucacas until the day before the eclipse.[1]

The negatives of the corona with both cameras show streamers to an extension of one and one-half solar diameters.

The type of corona is intermediate between that at maximum and minimum of sun-spottedness, resembling that of 1898 more closely than any other recent one. Five groups of good-sized prominences are shown at the bases of the four principal wings of the corona.

A series of well-marked hoods is shown over the prominence in the southwest quadrant in the negatives taken with the 11-foot camera. One of the comparatively rare, long, straight, very slender and nearly radial streamers is shown by these negatives in the northeast quadrant.

This streamer is seen to be composed of two distinct branches near the limb.

The chromospheric layer appears to have been of considerable depth.

Exposures for the two flashes were obtained with both prismatic cameras, as well as exposures on the corona. Owing to their great light-gathering power, particularly of the larger instrument, three exposures were given in place of a single one during totality.

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[1] The plates which were standardized before leaving Córdoba were somewhat mottled—due undoubtedly to having been exposed to the atmosphere two months before development.

No careful study of the plates has been made. A casual examination has not disclosed any features of special interest, however.

No trace of any gaseous radiations has been found in the corona proper.

These could hardly have been of any great strength or some of them would have been caught by the large prismatic camera, notwithstanding the unfavorable sky. The principal lines of the hydrogen series can be seen in the prominences in the exposures at mid-totality.

On the plate taken with the large instrument the spectrum is shown from λ3300 to λ7300. It extends some distance higher, but was cut off by the edge of the field. Bright lines are well shown to about λ5300. Below this the sensitiveness of the plate falls off considerably and at the extreme lower end only the D_3 and Hα lines are shown. These are both strong and the forms of some prominences are easily visible in them. Continuous spectrum extends to λ7300 or below.

About 40 lines can be distinguished in the spectrum above λ3600.

Probably the greatest value these observations will have is in the heights of the different vapors above the solar surface, which can be determined from them for comparison with similar results at other eclipses.

The spectrum with the slit spectrograph is faint and does not extend beyond the extreme inner corona. It is strong enough, however, to be able to say with certainty that there are no dark lines. It is equally certain that any dark lines could not have been "burned out." The slit was placed east and west across the Sun's diameter.

The spectrum extends 3′ on the east from the Moon's limb and not over 1′ on the west.[2] It appears to be perfectly continuous on both sides without a trace of dark lines and with small bright points at H and K positions on the linear continuous spectrum on the west only.

This result is additional evidence in line with the explanation[3] found by the writer for the contradictory observations of the Fraunhofer spectrum, *viz:* that the inner corona is largely incandescent, whereas the outer corona shines chiefly by reflected photospheric light.

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[2] The exposure was stopped intentionally 20 seconds before the end of totality.

[3] *Lick Observatory Bulletin* **9**, page 61.

The evidence regarding the condition of the matter composing the corona, with the exception of the very small gaseous constituent, is now so strong, confirmed as it is by so many different methods of investigation, and so harmonious that it may be accepted with confidence. Briefly stated, it is that this matter is in the form of very small particles, either solid or liquid, or, what is most probable, both, and that within the region usually observed this matter is incandescent, the temperature being higher and the incandescence greater as we approach the solar surface.

The motions of the coronal matter and the causes of motion are not so well known, but it may be predicted that the greater part of these motions will be found to result from the explosive forces on the Sun's surface, gravitational action on the heavier particles and light-pressure on the lighter particles.

The photometric plates present some interesting results, chief of which appears to be that the prominences and chromospheric layer at the beginning of totality emitted more light than the corona proper. It may be possible to determine the total amount of light from some of the groups of prominences separately, as distinct rings can with some difficulty be traced on the negative taken near the end of totality.

The second and third contacts were well observed by Sr. Chaudet as follows:

1916, February 3, Tucacas mean time.

	Observed	Computed
Beginning of totality	$11^h\ 23^m\ 21^s$ A. M.	$11^h\ 23^m\ 21^s$ A. M.
End of totality	11 25 51 "	11 25 53 "
Duration	2 30	2 32

These agree very closely with the times obtained by the party from the Caracas Observatory. The computed times are given for comparison, the data being taken from the American Ephemeris and the correction of -10^s given by Ross in *Astronomical Journal* No. 681 having been applied. It will be seen that the beginning of totality agreed within the second and the end differed but 2^s from these predictions.

The position of Tucacas obtained by a commission from the Caracas Observatory is as follows:

Latitude	10°	47′.5	North
Longitude	68	19 .2	West of Greenwich

In conclusion, it is a great pleasure to testify to the aid received from the officials of the Venezuelan Government, both in Caracas and at Tucacas, and to the gentlemen who took part in the observations on eclipse day. Without this aid little of value could have been secured. As it is, a series of observations which is believed to be of considerable value was secured despite the interference from the unfavorable sky conditions. Just how valuable they are cannot, of course, be known until they have been closely studied. It is certain, however, that they contain definite information on several problems which will serve to aid in maintaining a nearly unbroken series of eclipse observations for half a century.

Detailed studies of the results when completed will be published in a special volume along with the very few of any value which were obtained at the eclipses of 1912 and 1914.

Observatorio Nacional Argentino,
Córdoba, June, 1916.

SITE FOR THE LARGE REFLECTOR OF THE ARGENTINE NATIONAL OBSERVATORY.

By C. D. Perrine.

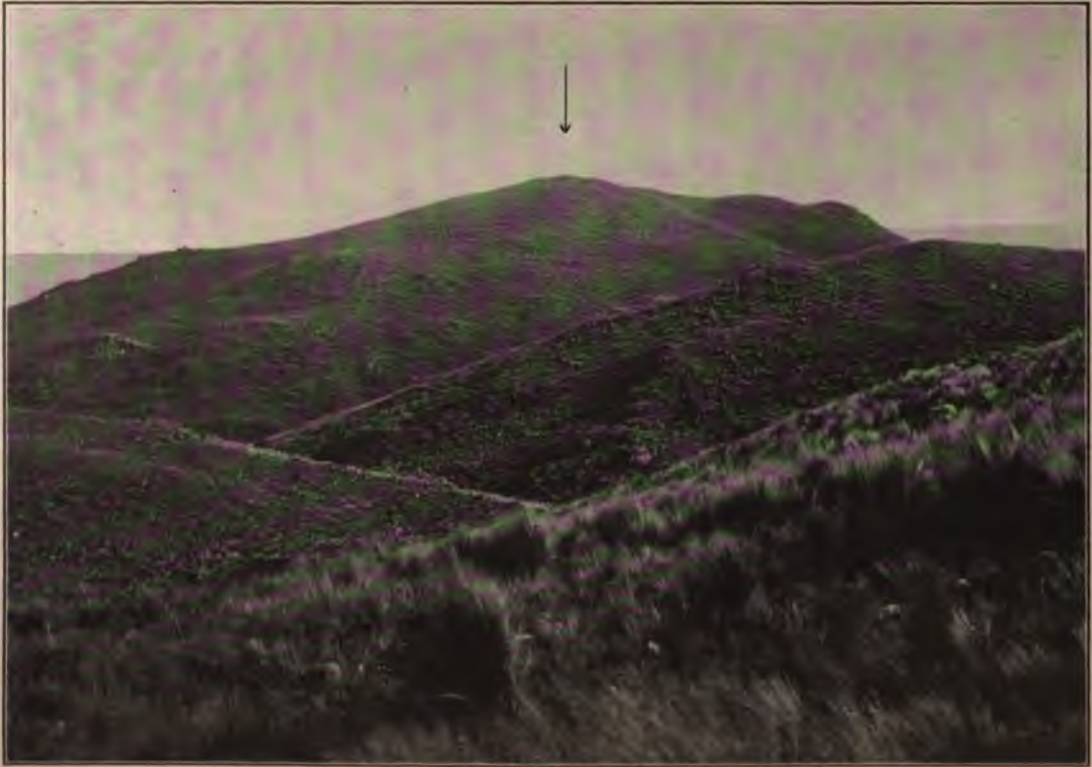
A site for the reflecting telescope of 1½-meter aperture, now in construction for the National Observatory of the Argentine Republic, has been chosen near the southern extremity of the Sierra Chica about 40 kilometers southwest of Córdoba. This range of mountains is some 200 kilometers in length and from about 1200 meters altitude at its southern extremity to nearly 2000 meters at the northern end where it connects with the much more extensive Sierra Grande farther to the west.

A considerable portion of this latter range is of exceptional interest. From a point almost due west of Córdoba where there is a group of needle-like peaks known as the Gigantes rising to altitudes of 2300 meters, the top of the range for over 100 kilometers to the south is a nearly level mesa averaging about five kilometers in width and over 2000 meters in altitude. The sides of this portion (particularly the west side) are steep and precipitous. The plains at the foot of this range vary from about 400 to 800 meters above sea-level. The mesa itself (known as the Pampa de Achala) is covered with a luxuriant carpet of grass and water is fairly abundant. Large herds of cattle are pastured on this pampa.

With the exception of the grass on the top, the vegetation in this region is scant.

The Sierra Chica is of the usual type of low mountain formation, resembling in general appearance the Coast Range to the west of Mount Hamilton, except that there is much less vegetation in the Sierra Chica.

The site selected for the reflector is a rounded knob 1200 meters above sea-level on the west side of the range, not far from its southern extremity, overlooking the valley between Chica and Grande. From its summit are visible Alta Gracia, the nearest railway station, 20 kilometers distant to the southeast; Córdoba, 40 kilometers to the northeast, and the extensive pampas for a long distance to the north, east and south, as well as the higher mountains to the west and north.



Site for the Argentine Reflector
(From the east)

The site is but a kilometer from the main new highway which crosses the Sierra Chica at this point from the plains at the east (Alta Gracia, Córdoba and the pueblito of Falda del Carmen) to the great estancia of Bosque Alegre (in the edge of which the site is situated) in the valley between the Chica and Grande, to the west. From Bosque Alegre the highway passes north some 30 kilometers to the southern end of Lago San Roque which supplies Córdoba with electric power and water and also an extensive region about with irrigation. At the southern end of this lake the road meets three others, one crossing the range to the east to Córdoba; one extending around the lake and to the north thru the valley to Cosquin, Capilla del Monte, etc., and a new road to the west, which crosses the Sierra Grande north of the Gigantes and gives access to the great valley region farther to the west.

This system of roads is probably the finest in the Republic. Many of them, including the one giving access to the Observatory site, are newly made within two years and all are macadamized for the greater part of their lengths, making a good system of automobile highways. For the most part the scenery is interesting and picturesque.

The site for the reflector, which comprises fourteen hectareas, is being donated by Mr. Henry Reynolds, owner of the estancia Bosque Alegre. It contains, besides the hill proper upon which will be located the telescope, an extension to the canyon to the south, in which is a small stream of perpetual water.

The hill is without trees, but is covered with a thick growth of tuft-grass, in many places waist high, which should be almost as good as trees as a protection against excessive heating and radiation.

Before anything was known of this site, many points in the mountains to the north had been explored and five of them tested by sending observers and instruments to secure meteorological observations and tests of the transparency and steadiness of the atmosphere. These stations were at altitudes of from 600 to over 1700 meters—or from 100 meters to 1200 meters above the surrounding pampa. Two of the stations were at altitudes of over 1700 meters, one just north of the Gigantes on the Pampa San Luis (which resembles to a considerable extent the higher Pampa de Achala, a little to the south), the other nearly a hundred kilometers to the north on the top of abrupt peaks. It was desired to test the high pampa regions especially, for if the astronomical conditions were good there, they were otherwise ideal for a station.[1]

Several facts stood out clearly from these observations which are of sufficient general interest to give here:

A. One hundred meters above the pampa was not enough to greatly reduce the diurnal range of temperature. The night range, however, was reduced to half or less.

B. Altitudes of 400 meters above the pampa (two stations) showed a reduction of diurnal range to 7° or 8° C. (half that on the pampa) and a nocturnal range of 2° to 3° Centigrade on clear nights.

There is reason to believe that under actual observing conditions the temperature range will be even more favorable than the results given above. Photographic observations at the two stations of intermediate altitude were made both at the beginning and end of 14 nights in early June and early November in 1913. The average interval of these 14 series was 8½ hours and the mean range of temperature 1°.07 C. In one of the series observations were also made about three hours after dark on all but one of the nights. Two of the remaining nights, one at each station, were abnormal, the temperature changing 3°.8 in one case and 4°.0 in the other. Omitting these two cases, the remaining 11 give an average interval of seven hours and an average range of temperature during that time of 0°.6 C. It seems probable, therefore, that on a majority of the better nights from about two hours after dark, the range of temperature should seldom exceed 1° C. in the open air. If any different, the site at Bosque Alegre should be slightly better than the two at which the above results were obtained. Altho the above data is limited, there is no reason to believe that it is not entirely representative.

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[1] The opinion has gained such currency here that it is the intention to move the entire observatory to the mountains that I take this opportunity to say that such is *not* the case. The practical advantages are so great of having all the work possible done in or close to a large city that it is intended to continue that policy and only make such observations in the mountains as require the better conditions found there, reducing and discussing even these observations to a large extent in Córdoba. The location of the Observatory on the bluff overlooking the city of Córdoba is satisfactory for meridian circle work and for most photographic work with small and medium sized telescopes.

Simultaneous observations in Córdoba gave a mean range of temperature of 6° C. for the same intervals, *falling* temperature in practically all cases.

C. Altitudes of 1200 meters above the pampa (two stations) gave a diurnal range of temperature of 4°.6 and 6°.2 C. (one-third that on the pampa) and nocturnal ranges of about 2° C.

The conditions at these high points were variable, due to the high gusty winds, and much less suitable for observing than lower altitudes.

D. At 100 meters above the pampa there appeared to be no more wind at night than on the pampa—where it is usually almost perfectly calm. Even during stormy weather it is the rule for the wind to cease entirely at night at the Observatory.

The two stations of mid elevation showed considerably less wind at night than in day time, but usually a breeze of from 5 to 15 kilometers per hour.

The two high stations showed strong winds most of the time, highest at night, when they often reached 50 and 60 kilometers. There appeared to be little choice between the high small pampa and a peak in either the matter of temperature or wind.

E. On account of the wind it is difficult to draw any very reliable conclusions as to the steadiness and smallness of image, the observations being photographic, and adequate wind protection being impossible under the circumstances. To the naked eye the stars were very steady and free from twinkling under all normal conditions.

F. The transparency of the air at all altitudes is good. At the higher altitudes the sky was very black. I have never seen the sky darker right up to the limb of the Sun than at one of the 1700-meter stations.

The details of the observations made at these different stations will be published in a volume of the *Resultados.*

A site had been selected about 300 meters above and near to the generating station of the electric company at Casa Bamba, and negotiations had been under way for some time for a site when the location at Bosque Alegre was brought to my attention. The accessibility of this point, together with the favorable appearance of other conditions, caused me to send an expedition and obtain a series of meteorological observations similar to those at the other points. The results were so favorable, slightly better than at any other point, that the offer of sufficient land by Mr. Reynolds was at once gladly accepted.

Notwithstanding its altitude, the wind was consistently less at night than in the day time, as favorable in that respect as any of the other stations tested except possibly the very lowest. The day-time winds at the Bosque Alegre site averaged 19 kilometers per hour.

The ranges of temperature were essentially the same as at the other stations tested, for the same altitude.

The number of clear nights will not differ greatly among the points tested nor from those available in Córdoba. The higher mountains are occasionally observed to be covered by clouds when it is clear on the pampa, so that there may be slightly fewer nights clear there. This is by no means certain, however, for the reverse has been observed in a few cases, and there are some conditions which would probably tend to equalize the above possible disadvantage.

There is one condition which is general in all this region and which is of prime importance for long programs of observation. The clear nights are distributed thruout the year with considerable uniformity. There are fully as many clear nights in winter, on the average, as in summer, and usually a slight excess.

The land has been surveyed, boundary monuments erected, and the site for the dome cleared almost to the level for the foundations for the walls. The road to connect the Observatory peak with the main highway is nearly completed, and a small catchment reservoir in a nearby gulch, to provide water for building purposes, has been constructed.

The parts of the dome are in Alta Gracia, awaiting the completion of the connecting road to be hauled to the summit.

As soon as the freezing weather is over it is hoped to commence the walls and to complete them during the summer, ready for the mounting of the dome the following winter, or sooner if possible.

The back of the large mirror has been ground and polished, the edge is ground and grooved, and the 90^{cm} flat for testing is nearing completion.

Observatorio Nacional Argentino,
Córdoba, June 29, 1916.

COMMENTS ON THE DAYLIGHT SAVING PROBLEM.

By W. W. Campbell.

[The following comments on the subject of "daylight saving" were prepared by request of the Chamber of Commerce of one of the great cities of the United States. Answers to five questions were asked for. The questions are not here printed, but their substance may be inferred from the comments.]

FOREWORD.

The time system which prevailed in the United States prior to 1884 was a hodge-podge that could not be endured by a progressive people. The Standard Time system now in use brought order out of confusion, except in a few far-western intermountain localities where the railroads have carried the system to excess for their own convenience. There are today certain proposals for "saving daylight" which threaten a return of confusion in the time system.

The problem of daylight saving is a much more difficult one for our very large country, extending over 59° of longitude, than it is for the small European countries, France, Germany, Switzerland, Italy, Denmark, Norway, Sweden, Great Britain, only one of which extends (very slightly) over more than 15° (one hour) of longitude. The European experience of the past summer was not under normal conditions, and was therefore not a fair test. It was under war conditions, when people will do anything that their governments request. It is not surprising that northeastern Germany, which was working thirty minutes or more behind Sun time, should want the working day advanced. Western Germany, including Hamburg, Bremen, Frankfort and the Rhine provinces, which formerly worked twenty to thirty minutes ahead of the Sun, are now working from one hour and twenty minutes to one hour and thirty minutes ahead of the Sun. It does not follow that the Rhine provinces will consent to this extreme advance of the working day in years of peace.

Great Britain (not including Ireland) ran with clocks advanced one hour during the months of the past summer, but the clocks were changed back to the old system on

October 1. There was considerable dissatisfaction with the new system, even for the summer months, and a commission of inquiry has been appointed to determine whether the advantages exceeded the disadvantages, with reference to deciding what time system the Kingdom should use next summer.

The experience of the city of Cleveland is not a test of the question. For a long time Cleveland was running on the 90th meridian time; that is, thirty-three minutes slow of the Sun. The marvel is that Cleveland endured the situation so long. It is no surprise and no test of the main question that Cleveland should belatedly prefer running twenty-seven minutes fast, winter and summer, to running thirty-three minutes slow, winter and summer. The case of Detroit is analogous. After working for many years with clocks twenty-eight minutes slower than the Sun, it is no surprise that their experience of the last year should lead them to prefer clocks thirty-two minutes fast over clocks twenty-eight minutes slow.

QUESTION I.

I favor the daylight saving plan if not carried to extremes, and if accomplished without introducing confusion in the time system of the community, nation and world.

QUESTION II.

I favor it chiefly in order that the day's work may be completed in time to give daylight out-of-door recreation to workers and workers' families. The middle of the work day in nearly the whole of our country, and in essentially all other countries under normal conditions, falls later than the middle of the Sun day, which is unfortunate. The ten-hour labor day, 7:00 A. M. to 6:00 P. M., and the eight-hour labor day, 8:00 A. M. to 5:00 P. M., have their mid-point one-half hour after the Sun is on the meridian. The office day, 9:00 A. M. to 5:00 P. M., has its mid-point at 1:00 P. M. The modern store day, 9:00 A. M. to 6:00 P. M., has its mid-point at 1:30 P. M. The practical result of these hours is that workmen, store clerks, etc., are freed from their duties so late in the day that after reaching their homes and eating their dinners the daylight hours are gone, except in the early summer months. Healthful and economic recreation is in essence denied them, and for diversion too large a proportion have no other recourse than the cheap shows with poor programs and poorer atmosphere. Many workers are not tempted to healthful recreation because the night hours are on.

The saving of eyesight and the saving of illumination bills are important, but in a minor degree.

The advancing of the work day by too great an amount would be objectionable. Those who prepare the breakfasts would have to get up too early. In the cities, where there are many hot nights in the summer months, it would send the families to bed too early in hot and stuffy bedrooms where restful sleep is not possible, and it would rout the families out too early in the cool of the morning when they could sleep restfully. It should be remembered that the Sun always has been the ruler of the day and I think it always will be. The law-making powers should not try to force the people too far out of step with the Sun: that would probably lead to successful resistance.

QUESTION III.

I do not think that daylight saving on a nation-wide basis, by such simple act of Congress as that of setting the clocks one hour ahead, is practicable. Our country is too big. The present Standard Time system is fine, the people are accustomed to it and like it. It could doubtless be improved in certain regions; for example, in eastern Ohio, western Pennsylvania, eastern Florida, southern Arizona, etc., where the clocks are thirty or forty minutes slow of the Sun. There are many other great regions, such as the central parts of the Dakotas, Nebraska, Kansas, Oklahoma, Texas, etc., where the clocks are running from thirty to forty minutes in advance of the Sun. If the work day were set forward one hour by national action, many regions would be operating more than an hour and a half in advance of the Sun, which is too much. I think that no community should be asked to work more than one hour in advance of the Sun, under normal conditions, even in the long summer months.

QUESTION IV.

I should be glad to have the work day in advance of the Sun during the summer months, beginning with 2:00 A. M., May 1, and ending at 2:00 A. M., October 1; and to have the work day in the winter months not appreciably behind the Sun day, but as nearly coincident with the Sun day as is practicable.

There is no point in delaying the summer advance until June 1. Thruout the United States the Sun rises less than two minutes later (by the clocks) on June 1 than it does on June 22. It rises earlier (by the clocks) on June 1 than it does on July 1. The daylight is as long on April 1 as on September 12. It is as long on May 1 as on August 12.

The public would not like to begin the summer advance when the weather is still cold. April 1 is too early for the the change. If the first morning of the new system should be cold and stormy, the change under the unfavorable conditions would create prejudice on the part of those who do not think twenty-four hours ahead.

May 1 is a better time to start, as the weather will in general be warm, and the people will then be longing for out-of-door life.

October 1 is a favorable time to change back to the winter system, because the latter half of September in the United States is generally fine out-of-door weather; and there is the further fact that the Sun rises ten minutes earlier and sets ten minutes earlier than the clocks indicate, owing to what astronomers call the equation of time. The people will not want to change their habits while the good weather lasts. Up to October 1 nearly everybody would have the extra daylight for recreation.

QUESTION V.

It is not certain that a satisfactory basis of change has yet been proposed. In my opinion the Standard Time system should remain essentially as it is, and daylight saving should be accomplished by other means than that of changing clocks forward in the spring and backward in the fall. The clock system should be settled correctly once for all, and be left unchanged. There is, of course, the psychological point that the people are accustomed to stopping for the noon hour when the clocks indicate twelve, and many will be inclined to say that a change in that custom will be difficult to establish. A change in the clock reading of the noon hour might cause slight confusion, but it would not last more than a day or two. I would suggest as a basis for daylight saving that the legislature of each state decide what the noon hour for state and county officials, public schools and other state institutions shall be, and what the hours for banks and courts shall be. For example: in Ohio, that the noon hour in winter, October 1 to May 1, shall be 11:30 to 12:30 Central Standard time, and in the summer 11:00 to 12:00 Central Standard time. Correspondingly, I would suggest that the six New England states decide for the same noon hours as above, but in Eastern Standard time. Congress could fix the hours for the District of Columbia, and decree that the hours for United States courts and United States officials and employees within the various states should conform to the local legal hours. An established noon hour for school children and government officials, and established banking hours, would be very strong incentives for all manufacturing concerns, stores, etc., to have the same noon hour, and to make the corresponding advance in the times of beginning and ending the day's work. If there should be individuals and institutions which decline to advance their work day, the same individuals and institutions would probably decline to advance their work day if the device of setting all clocks forward a half hour or an hour were ordered by the Government.

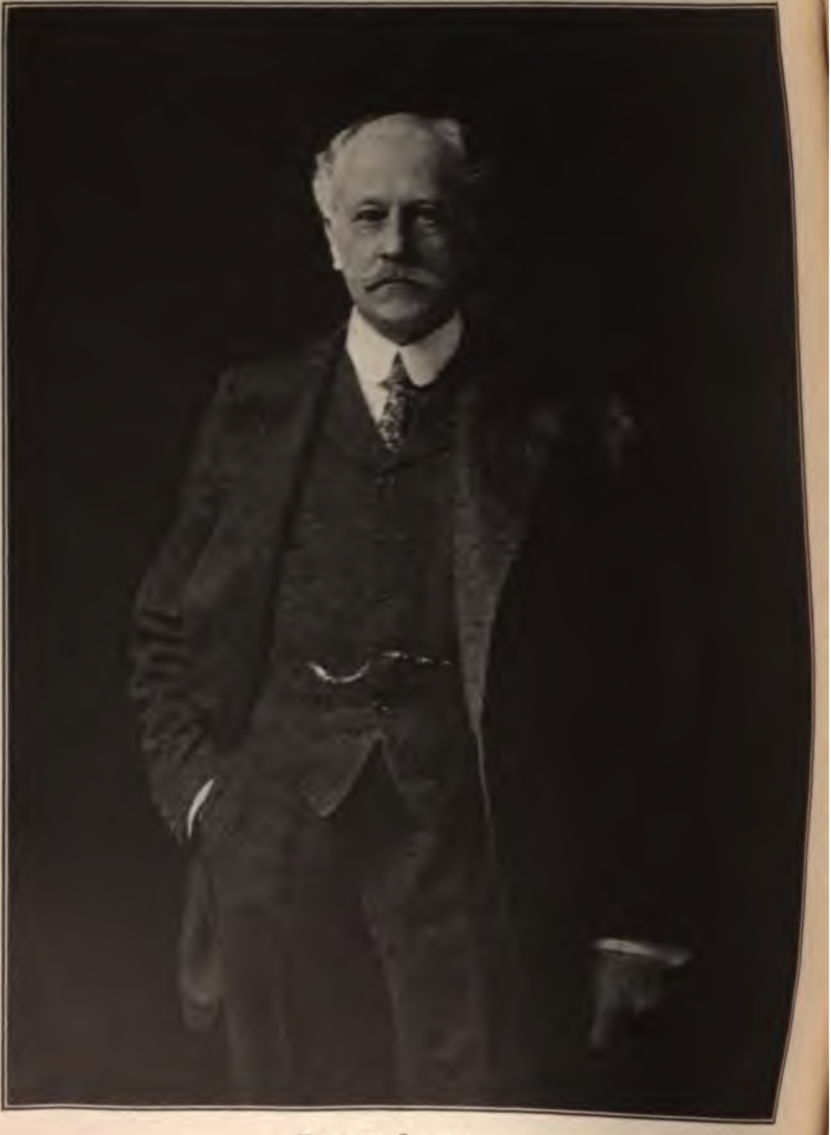
I admit that uncertainty exists as to how far the psychological element of dependence upon the actual reading of a clock face will control the decisions of individuals and organizations.

To the act of falsifying the time by setting the clocks thirty minutes or sixty minutes fast there is very little *technical* objection. Records of events which ought to be made in absolute time, so that the instant of happening could be located precisely at any future date, could still be made in one of the existing definite systems. Interest in the precise time when an ordinary event of daily life occurs vanishes very quickly. Outside of the domain of pure science we almost never go back a month or a year to inquire as to the precise second or minute or hour when something happened. The morning or the evening, the forenoon or the afternoon, the day or night, are usually sufficient. The lack of a logical time system before the year 1884 does not embarrass us today. However, the changing of clocks by cities, localities or states would produce a certain amount of confusion which we ought to avoid if possible. I think we should not throw the clocks out of step with those of surrounding localities, those of other other states, and those of other nations. The changing of all the clocks in the United States by national decree would produce a certain amount of confusion. For example: if the Canadian Government did not institute the same practice there would be confusion along the boundary line.

I think that city authorities should be slow to act. A suitable commission ought to consider the problem for a large group of states, such as the New England states, or for the nation. The falsifying of clocks should be avoided if possible.

QUESTION VI.

None of the methods thus far proposed would affect the daily life of the Lick Observatory, but we should not like to have our clock faces read Denver time, as they would if the state or nation ordered all clocks to be set forward one hour.



Percival Lowell

PERCIVAL LOWELL.

By the sudden death of Dr. Percival Lowell, at Flagstaff, Arizona, on November 13, America has lost one of her best-known astronomers, a man who made large contributions to the advancement of his chosen science not only by his own observations and studies, but also by building and maintaining at his personal cost an observatory equipped with powerful telescopes and accessory instruments at which a staff of expert observers coöperated in his researches.

In addition to these services he has done more, by his charming books and his popular lectures, to interest the general public in astronomy than any man since Newcomb.

In the public mind Lowell's name is associated almost exclusively with the planet *Mars* and, in particular, with the theory he advocated so skilfully that our neighbor planet is the abode of intelligent life. *Mars* did, in fact, receive more of his own attention than any other object; but his personal observations extended to all of the planets of our system from *Mercury* to *Saturn* (and, to a lesser degree, to *Uranus* and *Neptune*), and the Lowell Observatory, under his direction, has also made important contributions to our knowledge of the stellar universe, particularly by the discovery and measurement of double stars and by photographic and spectrographic investigations of the spiral and other nebulæ. The energy and enthusiasm with which Mr. Lowell and his associates have worked since the foundation of the Lowell Observatory in 1894 is made manifest by the three large quarto volumes of the "Annals of the Lowell Observatory," and the seventy-three "Bulletins of the Lowell Observatory" which have already been issued. Last year, in addition to these, Mr. Lowell began the publication of a series of "Memoirs of the Lowell Observatory," containing theoretical researches in celestial mechanics. The two memoirs so far distributed contain his personal studies of the problem of a Trans-Neptunian planet and of the structure of *Saturn's* rings.

To these technical works must be added his widely known books "The Solar System," "Mars and its Canals," "Mars as the Abode of Life," and "The Evolution of Worlds"; and his numerous popular lectures. Only a month before his death he delivered at Berkeley and at Stanford University the last two addresses of a lecture tour among the colleges of Idaho, Washington, Oregon and California.

His astronomical researches by no means absorbed all of Mr. Lowell's energies; he was, indeed, a man of wide interests and of many-sided ability. Long before he founded the Lowell Observatory he had established a reputation as a student of Oriental life and as a writer of books on travel and study in Japan; and with all his literary and scientific work he found time to exercise his keen business ability in the accumulation and administration of a large fortune.

Many astronomers have been unable to adopt Mr. Lowell's point of view on some questions or to agree with all of his conclusions, but every one interested in astronomy appreciates the great value of his work in extending our knowledge of the planets of our system, and admires the generosity with which he has supported the observatory which bears his name. His researches have been recognized by the award of the Janssen Medal of the French Astronomical Society; by the award of the Gold Medal of the Mexican Astronomical Society; by honorary degrees conferred upon him by American colleges; and by honorary membership in the Royal Astronomical Society of Canada and in other societies.

We deeply regret his death while still in the prime of his power as an observer and as a student—he was only 61 years old—and sincerely hope that such provision has been made for the Lowell Observatory at Flagstaff, that it may continue his work and remain as a permanent memorial to him.[1]

ROBERT G. AITKEN.

November 16, 1916.

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[1] Definite information has been received since these lines were written to the effect that Dr. Lowell's will provides for the continuation of the work of the Lowell Observatory.

KARL SCHWARZSCHILD.[1]

The war exacts its heavy toll of human life, and science is not spared. On our side we have not forgotten the loss of the physicist Moseley, at the threshold of a great career; now, from the enemy, comes news of the death of Schwarzschild in the prime of his powers. His end is a sad story of long suffering from terrible illness contracted in the field, borne with great courage and patience. The world loses an astronomer of exceptional genius, who was one of the leaders in recent advances both in observational methods and theoretical researches.

Karl Schwarzschild was born on October 9, 1873. His mathematical ability developed with almost precocious rapidity. His first scientific papers, relating to the theory of determining orbits from observations, were published in the *Astronomische Nachrichten* in 1890; they show such wide reading combined with original insight that it seems almost incredible that the author was a schoolboy of sixteen. On taking his university course, he studied at first at Strasburg under Becker, and afterwards at Munich. There he came under the inspiration of Seeliger's teaching, which apparently was the basis of his later researches on stellar statistics; he often expressed regret that the work of Seeliger was so little understood in other countries. His career after leaving the university is divided into three stages: he was at first Assistant in the von Küffner Observatory, Vienna; in 1901 he became Professor and Director of the Observatory at Göttingen; finally in 1909 he succeeded Vogel as Director of the Astrophysical Observatory, Potsdam.

Schwarzschild's researches were amazingly varied. He was a master of almost all branches of physical and mathematical science. It is difficult to pick out any one work as his special title to eminence; for it was not his way to write exhaustive memoirs—to wring his subject dry. He made his contribution—some clear-cut theorem marking a definite advance, which others might follow and carry out in detail—and then he passed on to some new point on which his genius could throw light.

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[1] We reprint this admirable summary of the work of a great German astronomer from the English astronomical journal, *The Observatory* (August, 1916), both because it is the most adequate account of Schwarzschild's scientific career that has been published and because it is a fine example of that spirit of generous appreciation of an enemy's greatness which should characterize all honorable men, but which seemed, for a time, to be in danger of being lost in the present war.
PUBLICATION COMMITTEE.

In practical astronomy perhaps his chief work was his determination of photographic magnitudes. This was one of his earliest researches, being started at Vienna and developed at Göttingen. His method was to draw out the star-image into a uniform patch of light, of which the density or greyness could be measured in order to ascertain the brightness; this spreading out of the image was accomplished partly by displacing it out of focus and partly by making it travel in a definite manner over an area of the plate. With the coöperation of his assistants at Göttingen, he compiled in this way the "Göttingen Aktinometrie," a catalogue of photographic magnitudes of stars between Dec. 0° and +20° down to the limit $7^{m}.5$, reduced to an absolute scale. This work brought out very clearly the close relation between the colour and spectral type of a star, and also the fact that it is the stars of intermediate colour—the yellow stars—which have the largest proper motions.

In this connection it may be mentioned that Schwarzschild was the first to employ a coarse grating in front of a telescope object-glass—a plan which is now often used both for determining photographic magnitudes and measuring star colour. Schwarzschild, however, did not apply it to these purposes, but measured the separations of double stars with it, using it as a kind of double-image micrometer; he varied the distance between the two images by inclining the grating at different angles to the axis of the telescope. The method does not seem to have been tried on a large scale, though the experiments with a small telescope gave good results.

To Schwarzschild we owe the theory of radiative equilibrium of the Sun. It seems probable that this theory represents the observed phenomena better than any other; but, like much of Schwarzschild's theoretical work, the value lies not so much in the correctness of the physical assumptions as in the clear formulation of the problem, enabling us to appreciate the possible alternatives and the manner in which they affect the solution. His great step was to recognize that there are three types of equilibrium of the Sun's atmosphere according as conduction, convection, or radiation is the most effective in transferring heat. By working out the last alternative he brought the theory into a fit state to be compared with observation, and the value of this would have been none the less great even if observation had been far less favourable to the radiative hypothesis than was actually the case.

Another important result was his calculation of the pressure of radiation on small solid particles—of much interest in connection with the repulsion of the tails of comets by the Sun. For moderately large particles sunlight exerts a pressure proportional to the cross-section, whereas the force of the Sun's gravitation is proportional to the cubical contents. It follows that as the size of the particle decreases the light-pressure decreases less rapidly than the gravitation, so that ultimately the former predominates and the particle is repelled from the Sun. But the repulsion does not increase indefinitely, because, when the size of the particle becomes comparable with the wave-length of light, diffraction takes place. For a very small particle the light-waves bend round instead of being stopped. There is thus a certain size of particle for which the repulsion is a maximum, and Schwarzschild calculated that this upper limit is about 19 times the solar attraction. In view of the fact that the repulsive forces observed in comet's tails are sometimes considerably greater than this, this limit to the efficacy of light-pressure is of great interest.

In stellar statistics Schwarzschild's best-known work was his ellipsoidal hypothesis of stellar motions. Kapteyn had in 1904-5 published a summary of his celebrated investigation which showed that there are two streams of stars. In later work, for the purpose of precise mathematical treatment, it had seemed best to take the two streams quite literally, and represent the motions as due to two independent systems of stars passing through one another. Schwarzschild, however, proposed a mathematical treatment of the phenomena, which retained the essential unity of the system; the double-streaming was, of course, duly reptesented in his formulæ, but he avoided any suggestion that it arose from the encounter of two clusters. The ellipsoidal hypothesis is a most elegant piece of mathematics, and is specially adapted to simplify many of the problems of stellar motions which have arisen. Without it much of the recent progress would have been impossible. It is characteristic of Schwarzschild that his whole work on this subject, which has had so great an influence on stellar investigation, is contained in two papers of 28 pages in all. He made many contributions to other branches of stellar investigation which are too technical to be described here: but it may be mentioned that his general solution of the integral equation of stellar statistics appears to be not only of astronomical value but a noteworthy contribution to pure mathematics.

Professor Baker, in the last number of the *Observatory*, brought to light the almost forgotten fact that an important point in the theory of exchange of stabilities in dynamics is due to Schwarzschild. Outside astronomy, his papers ranged over geometrical optics, electrical theory, thermodynamics, and the navigation of balloons. His last work was a paper on the Quantum Theory published by the Berlin Academy of Sciences; he corrected the proofs on his sick-bed.

Schwarzschild's characteristics were not those which are usually associated with the scientists of his nation. Keen and restless, his nature was remote from the slow-plodding German character. He was a most enthusiastic mountaineer, and had accomplished some of the most desperate ascents in the Alps. He was full of the adventurous spirit, in winter sports in Switzerland, in early Zeppelin ascents—and in the last great adventure of all. His writings are a model of clearness and concise expression; he never inflicts on us the unbalanced detail and the mazes of analysis—the penalty of "German thoroughness"—which render so many German scientific writings unattractive. He goes straight to his point without an unnecessary sentence. It would be paying an ill-service to the memory of one who gave the final proof of devotion to his country, to seek by these traits to disassociate him from the rest of his nation. We would rather say that through him a new spirit was arising in German astronomy from within, raising, broadening and humanizing its outlook; and we are confident that he has left behind an influence which will enlarge and revivify the old traditions.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1917.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon...	Jan. 7th,	$11^h\ 42^m$ P.M.	Full Moon..	Feb. 6th,	$7^h\ 28^m$ P.M.
Last Quarter.	" 16th,	3 42 A.M.	Last Quarter	" 14th,	5 53 P.M.
New Moon...	" 22d,	11 40 P.M.	New Moon..	" 21st,	10 9 A.M.
First Quarter.	" 29th,	5 1 P.M.	First Quarter	" 28th,	8 44 A.M.

The year 1917 will have the maximum number of *eclipses*, seven. Of these, three are of the Moon and four of the Sun. There will not be another year with seven eclipses until 1935, and then there will be two of the Moon and five of the Sun. The last previous occurrence of this latter phenomenon was in 1823. Three lunar eclipses occurred in 1908, but in that year there were only three solar, making a total of six. The average number of eclipses per year is four or five, but the number may be as low as two. In this case, which happened in 1904, both of the eclipses were solar and both central.

There will be two eclipses during January; the first is *a total eclipse of the Moon* on the night of January 7-8, and will be visible thruout the United States. The circumstances of the eclipse are as follows, Pacific Time:

Moon enters shadow	Jan. 7th,	$9^h\ 50^m$ P.M.
Total eclipse begins	" 7th,	11 0 P.M.
Middle of the eclipse	" 7th,	11 45 P.M.
Total eclipse ends	" 8th,	12 29 A.M.
Moon leaves shadow	" 8th,	1 39 A.M.

The duration of totality, not quite an hour and one-half, is longer than the average, although not a maximum.

The second eclipse of the year occurs on January 22-23, and is *a partial eclipse of the Sun*. It will not be visible in the Western Hemisphere. The regions of visibility are Europe, except the British Islands and Spain, Northern Africa and Western Asia. The greatest obscuration of the Sun is not quite three-quarters of its diameter.

The Earth is in perihelion, that is, at its least distance from the Sun, on January 3, 4 A. M. Pacific Time

Mercury is an evening star at the beginning of the year, coming to its greatest east elongation on the evening of January 2. Its distance east of the Sun is then 19° 22′, and it remains above the horizon for about an hour and a half after sunset; so that it is in good position for naked-eye observation in the evening twilight. This favorable condition lasts only a few days, as the distance between planet and Sun begins to diminish rapidly, more so than is usual, as the planet passes perihelion about midnight January 11. Conjunction with the Sun comes on the evening of January 18, and thereafter until March 29 the planet is a morning star. It reaches its greatest west elongation on the early morning of February 12 and is then 26° 3′ west of the Sun, nearly 7° farther from the Sun than it was on January 2, but as it is in February 8° farther south than the Sun it will rise only a little more than an hour earlier. It may, however, be seen in the morning twilight for a few days about the middle of the month. *Mercury* is in conjunction with *Mars* on January 13, only five days before conjunction with the Sun and on January 30, twelve days after conjunction with the Sun it is in conjunction with *Venus*, but in both cases the planets are too near the Sun for a naked-eye view.

Venus is a morning star thruout the period, rising about two hours before sunrise on January 1. This interval gradually diminishes to about half an hour at the end of February; but the great brightness of the planet will allow it to be seen in the morning twilight during a considerable part of the period. The planet is of much less than average brightness, as it is nearing superior conjunction and therefore greatest distance from the Earth. There is a close conjunction with *Uranus* on February 24, but both planets are too near the Sun for naked-eye visibility.

Mars is still an evening star, but is being gradually overtaken by the Sun in their common eastward motion, and conjunction is reached on the last day of February. It will hardly be possible to see the planet at any time during the period, as it sets only about an hour after sunset on January 1, and the interval diminishes to zero by February 28. It is in close conjunction with Uranus on February 2. On February 20 it is in perihelion, or at about the same date as it reaches its maximum distance from the Earth.

Jupiter is in fine position for evening observation in the western and southwestern sky. On January 1 it does not set until an hour and one-half after midnight; and altho it is drawing continually closer to the Sun it remains above the horizon until 10 P. M. on February 28. It moves during the period about 6° eastward and 3° northward from the constellation *Pisces* into *Aries*. No bright stars are near it.

Saturn also is in fine position for evening observation, coming to opposition with the Sun on January 17, when it is on the meridian at midnight and remains above the horizon all night. It is on the meridian about 20° degrees south of the zenith at 1^h 20^m A. M. January 1. Its motion among the stars is retrograde (westward) about 4° and 1° northward during January and February, from the western part of *Cancer* into the eastern part of *Gemini*. It is nearly on the extension of the line from *Castor* (*α Geminorum*) *to Pollux* (*β Geminorum*) not quite twice the distance from the latter that the stars are from each other, crossing this line from left to right during the period. As seen in the telescope the minor axis of the ring is a little more than one-third of the major axis, the rings being distinctly narrower than they were during 1916. There is a close conjunction with the Moon on the evening of February 4, which becomes an occultation for regions south of the equator.

Uranus is in the southwestern sky in the early evening during January, rather too close to the Sun for naked-eye observation. On February 8 it comes to conjunction with the Sun, and becomes a morning star, but does not get far enough away from that body for easy observation for several months.

Neptune comes to opposition with the Sun on January 23 and is therefore, except for its faintness, in fine position for evening view. It is in the constellation *Cancer* 8° east of *Saturn*, and is moving slowly westward.

ERRATUM.

An unfortunate misprint occurs in Dr. Crawford's note on the determination of the longitude of the Students' Observatory by wireless signals from Arlington in the August-October number of these PUBLICATIONS. Page 210, line 7, should read: "to about $0^s.1$."

PUBLICATION COMMITTEE.

NOTES FROM PACIFIC COAST OBSERVATORIES.

NOTES ON SOME A DOUBLE STARS.

A note in the December, 1915, number of these PUBLICATIONS, called attention to some of the double stars discovered in my survey which have shown decided orbital motion in the interval since their discovery. The continuation of the working program there described has revealed motion in a number of additional pairs. Eleven of these, which have been fully measured at the present epoch, are listed in the following table:

Star	Δ Epoch	Δ θ	ρ discovery	Δ ρ	Magnitudes
A75	16 .0	—48°. ±	0″.28	—0″.13	7.2—— 8.0
347	13 .7	—28 .2	0 .34	+0 .02	8.0—— 8.3
556	13 .2	+16 .0	1 .34	+0 .36	6.8——10.5
758, AB	12 .1	+20 .5	0 .28	—0 .01	9.1——10.5
764	11 .8	+21 .9	0 .41	+0 .05	8.0——10.0
772	12 .3	—22 .0	0 .25	+0 .03	8.7—— 9.0
961	11 .0	—57 .8	0 .18	+0 .09	8.8—— 8.8
980	10 .6	—13 .0	0 .34	+0 .06	6.8—— 8.2
1223	10 .6	—41 .5	0 .13	+0 .03	9.5—— 9.5
1281	9 .9	+31 .4	0 .45	+0 .02	9.5——10.0
1903	7 .8	+17 .1	0 .37	+0 .01	9.2—— 9.5

Measures of A75 in the years to 1907 show a slow diminution in distance with retrogade angular motion. Unfortunately, no measures were made in the years from 1907 to 1916 and the star is now so difficult an object that this year's measures are somewhat discordant. Measures of A980 in 1908 and in 1912 give positions intermediate between those of 1905 and 1916.

The pair A1281 is especially interesting, not only because the orbital motion is unusually rapid for a star as faint as 9.0 and as wide as this one, but because the Cincinnati observers assign to it the large proper motion of $+0^s.050$ in right ascension and —0″.36 in declination, which amounts to 0″.64 in the direction of 124°.4. Obviously this is common to the two components. The system is probably one of the nearer stars and should have a measurable parallax. Its position for 1900.0 is 2^h 44^m 54^s, + 45° 35′.

Three other stars of which I have as yet secured only one set of measures at the present epoch deserve mention. They are:

A351.

1902.48	65°.4	0″.55	4^n
1910.31	75 .8	0 .38	2
1916.58	220 .3	0 .19	1

The magnitudes are 9.5 and 9.9. The change in 1916 was so great that I checked the micrometer readings and the star's identification with special care and I am confident that the measure as given is free from mistake.

A519, magnitudes 8.8 and 9.0.

1903.04	273°.2	0″.39	3^n
1916.20	360 .±	0 .10	1

The pair was too close for accurate measure and the quadrant indeterminate. As in the case of A351, the identification of the star was carefully checked.

A1535, magnitudes 8.8 and 8.8.

1907.69	34°.1	0″.48	3^n
1916.79	63 .4	0 .35	1

Many other pairs have shown a change in angle of from 5° to 10° in the period from discovery to 1916.

One of the stars mentioned in my former note is A494, for which my measures in 1915 showed an apparent increase of angle amounting to 157°.8 in the twelve years since its discovery. The measures secured this year confirm this rapid motion, the angle having advanced 14°.6 in 1.06 years. There is little or no change in the apparent distance, which is about 0″.15.

ROBERT G. AITKEN.

PROFESSOR KEELER'S PHOTOGRAPHS OF NEBULÆ.

A limited number of copies of Volume VIII, *Publications of the Lick Observatory* (Professor Keeler's photographs of nebulæ and clusters made with the Crossley reflecting telescope), are available for distribution to astronomers, students of astronomy, observatories, university and college libraries, and other libraries of high character, upon payment of the mailing charges. The volume wrapped for mailing weighs five pounds and will cost sixty cents to send to points east of Chicago, to Canada, and to such foreign countries as have parcel post interchange with the United States. The rates for points west of Chicago may be ascertained from the local postmaster. Money order or stamps for transportation charges should accompany the request.

W. W. CAMPBELL,
Director, Lick Observatory.

NOTE ON BARNARD'S LARGE PROPER-MOTION STAR.

Two photographs of the spectrum of this star were obtained in June with the 60-inch reflector and the Cassegrain spectrograph. A camera of 7 inches focal length was used in conjunction with the 64° prism regularly employed in the instrument. The first of the two plates was considerably underexposed, but the second with an exposure time of five hours is of very fair quality.

The spectrum of the star is Mb with the peculiarities characteristic of the "dwarf" stars of this type. It is, in fact, nearly identical with that of Groombridge 34, Krüger 60, and several other stars of large proper motion and parallax. The line $\lambda 4454$ of calcium used in determinations of absolute magnitude is very strong, and this is also the case with the neighboring calcium line at $\lambda 4435$ and the titanium group at $\lambda 4535$. The absolute magnitude of the star of the basis of the calcium line is about 11.0 or 11.5. The apparent magnitude is still somewhat uncertain: if we assume the value 10.0 the parallax of the star would be about $+0''.2$. It will be of exceptional interest to compare this value with the results of parallax observers, since a considerably larger measured parallax would indicate the existence of stars of this type with a luminosity much lower than any yet known to exist.

The radial velocity of the star was determined from both photographs, the stronger iron lines and those of calcium being used for the purpose. The mean value from the measurements of three observers using from 8 to 10 lines is -94^{km}.

Walter S. Adams.

Some Recent Spectral Parallax Determinations.

In continuation of the determination of the absolute magnitude and the parallax of stars from certain characteristics of their spectra, a number of stars with well-determined measured parallaxes have been observed. Some of the more interesting cases of this kind are summarized in the following table. The double stars in particular form a useful test of the value of the method since the absolute magnitude differences in these cases should correspond to those in apparent magnitude. In the table M denotes absolute magnitude, and the references to measured parallaxes are to those by Slocum and Mitchell, Lee and Joy, Schlesinger and Russell. Kapteyn's compilation is indicated by the letter K.

				π		
	m	*Spectrum*	*M*	*Spec.*	*Meas.*	*Authority*
η Cassiop.	3.6 7.6	Go Ko	4.2 8.8	+0″.13 0 .17	+0.19	K.
T Ceti	3.6	G5	6.3	0 .35	0.32	K.
6 Persei	5.4	G3	—0.7	0 .01	0.00	L. and J.
O_2 Eridani	4.5	K1	6.5	0 .25	0.17	K.
A. Oe.4961	8.5	K5	8.7	0 .11	0.10	S. and M.
W. B. 5^h592	8.9	Ma	10.1	0 .17	0.18	K.
A. Oe. 9342	9.2 9.2	K9 K7	9.6 9.1	0 .12 0 .10	0.08	Green
43 Comae	4.3	G1	4.2	0 .10	0.12	K.
Ber. B. 5072	9.5	K7	8.6	0 .07	0.05	R., L. and J.
Pi 14^h212	5.8 8.7	K5 Ma	7.1 10.2	0 .18 0 .20	0.17	K.
δ Herculis	3.0	G1	2.3	0 .07	0.14	K.
W. B. I. 16^h906	8.8	Md	9.9	0 .17	0.13	L. and J.
Anon. 17^h 34^m +18° 36′	9.1	K7	10.2	0 .17	0.14	L. and J.
A. Oe. 17415	9.3	Mb	10.4	0 .17	0.22	L. and J.
Lam. 18180	9.4	K7	9.1	0 .09	0.07	R., Sch.
o Draconis	4.8	G9	6.7	0 .24	0.20	K.
β Aquilæ	3.9	G7	3.0	0 .07	0.07	M.
γ Delphini A	4.5	Ko	1.3	0 .02	0.07	M.

Walter S. Adams.

The Parallaxes of B. D. +35° 4001 and B. D. +35° 4013.

In the *Publications of the Astronomical Laboratory at Groningen*, No. 1, Kapteyn and Donner discuss the parallaxes of 248 stars in the region around B. D. +35°4013. The choice of the region of the sky covered by their plates had been determined by the fact that it contained three Wolf-Rayet stars. These three stars were also put on the Mount Wilson program and the parallaxes of two of them have been finished. The results are:

B.D. +35°4001 $\pi \text{rel.} = +0''.011 \pm 0''.005$ 16 exposures
B.D. +35°4013 $\pi \text{rel.} = +0''.002 \pm 0''.003$ 14 exposures

The measures and reductions were made in practically the same way as that described in *Contributions from the Mount Wilson Solar Observatory*, No. 111. To derive absolute parallaxes the values found should be corrected by about +0″.002. The absolute magnitudes are then +4.1 ±0.8 and +0.9 ±1.8.

The relative parallaxes of these two stars are given by Kapteyn as +0″.004 and +0″.032, respectively, corresponding to absolute parallaxes of +0″.008 and +0″.036, while the probable errors are 0″.025 and 0″.020. However, from a comparison of the mean parallaxes as given in *Groningen* 1, page 72, with those derived by Kapteyn in *Groningen* 8, page 28, it seems likely that these parallaxes need a magnitude correction. From a curve constructed from the values given in *Groningen* 1, page 72, it would seem that the necessary corrections for the two stars are —0″.014 and —0″.025, respectively, leaving as absolute parallaxes —0″.006 and +0″.011.

It is to be regretted that it has been impossible to derive also the parallax of the third Wolf-Rayet star, B. D. +36°3956, but this will have to wait until next year.

I should like to correct here an error made in the printing of the proper motion of 61 *Cygni*, as given in this JOURNAL, February, 1916:

61_1 Cygni μ_α should read = +4″.169 instead of +4″.107.

A. VAN MAANEN.

MAGNITUDES AND COLOR OF BARNARD'S PROPER-MOTION STAR, $17^h\ 53^m\ 44^s + 4°\ 27'.8$ (1916)

The photographic and photovisual magnitudes of Barnard's large proper-motion star have been determined by direct comparisons of the field with the North Polar Standards. Exposures on Seed 27 and Cramer Isochromatic plates (the latter behind a yellow filter) were made with the 60-inch reflector of the Solar Observatory in the usual manner. Measures of two pairs of photographs exposed on different nights gave the first of the following series of results:

	Polar Comparisons	Adopted
Photographic Mag.	11.67	11.43
Photovisual Mag.	9.67	9.67
Color Index	+2.00	+1.76

The color index was also derived by the method of exposure ratios. Four isochromatic plates were exposed as follows (two nights):

With yellow filter	16, 32^{m}	(Yellow images)
Without filter	2, 4, 8, 16^{m}	(Blue images)
With yellow filter	16, 32^{m}	(Yellow images)

From the images on these plates it was found that the ratio of exposure times producing blue and yellow images of the same size is 0.434, which, for the emulsion used, corresponds to a color index of 1.76 ± 0.03 (P. E.) mags. This agrees well with the spectrum, which is Mb, and is much more reliable than the value given above, as the photographic magnitudes obtained from the polar comparison plates are discordant and uncertain. Since the photovisual magnitudes are probably reliable, the adopted photographic magnitude is that obtained by combining the mean photovisual magnitude with the color index.

The following are approximate results for the neighboring bright star B. D. +4°3560 ($8^{m}.7$):

Photographic Mag.	9.1
Photovisual Mag.	8.9
Color Index	+0.2

FREDERICK H. SEARES.

THE PHOTOGRAPHIC MAGNITUDE OF THE NINTH SATELLITE OF JUPITER.

The brightness of the Ninth Satellite of *Jupiter* has been determined by direct estimates of images on two photographs made with the 60-inch reflector. Both plates have equally-timed exposures on the Polar Standards and on the satellite field. The data relative to the plates and the magnitudes obtained from them (corrected for atmospheric extinction) are as follows:

Plate	Date	Length of Exposures	No. Comp. Stars	Pg. Mag.
3484	1916, Oct. 18	32^m	7	18.29
3487	Oct. 19	32	7	18.32

The adopted photographic magnitude, 18.3, applies to a time five days before the present opposition. Reducing to the mean opposition we obtain magnitude 18.6. On the basis of this determination the photographic magnitudes of the seventh and eighth satellites are between 17.5 and 18.0.

The size of the Ninth Satellite is readily computed once we know the albedo. Estimating the color-index at one magnitude and assuming a value of the visual albedo similar to that of the Moon, *Pallas*, and *Ceres* ($p = 0.1$ in Russell's formulæ, *Astrophysical Journal*, **43**, 177, 1916) we find that the angular diameter at mean opposition is 0″.009. If we assume a higher reflecting power, for instance $p = 0.25$, a value near that of *Juno*, the diameter is 0″.006. The comparison of this satellite with the asteroids is obviously better than assuming for it a close similarity in reflecting power to the four largest satellites of *Jupiter* for which the mean value of p is 0.35.

The linear diameter of the Ninth Satellite at mean opposition is 17.4 miles on the first assumption above, and on the second is 11.2 miles. The true value is probably within these limits.

SETH B. NICHOLSON.
HARLOW SHAPLEY.

A NEW VARIABLE STAR.

In the course of the investigation of star colors in the southern globular cluster Messier 9 (N. G. C. 6333) several objects have been found for which the light apparently varies thru small intervals. One star, however, whose position with respect to the center of the cluster is

$$\Delta\alpha = 7^s.4 \qquad \Delta\delta = -1'18''$$

shows a conspicuous short-period variation. It is brighter than normal on plates made April 26 and June 4, 1916, and of intermediate brightness or faint on March 29, April 27, April 28, July 6 and July 7, 1916. From compairsons with Polar Standards it appears that the range of variation is in excess of a magnitude. At maximum the star is photographically fainter than magnitude 16.5. It is, therefore, probably the faintest variable star so far discovered.

Harlow Shapley.

On the Observed Rotations of Planetary Nebulæ.

Our spectrographic observations for the detection of evidences of rotation in the brighter planetary nebulæ, reported upon in these Publications, Vol. 28, pp. 119-20, June, 1916, have been continued during the summer and fall months. We have tested nearly forty planetaries. About twenty give definite evidence of rotational motions, or relative motions within the nebulæ. For a half dozen others we suspect that the nebular lines are inclined to their normal directions in some cases and distorted from straightness in others, as Doppler effects resulting from motions. In about fifteen cases no indications of rotation or relative motion within the nebulæ have been found.

In general the larger planetaries, and in general the nebulæ whose elliptic outlines have the greatest eccentricities, give the strongest evidences of rotation or internal motion.

The smallest nebulæ and the nebulæ whose outlines are most nearly circular are the ones in which the tests for rotation have failed. Failure with very small nebulæ may arise from the difficulty in guiding with sufficient accuracy throughout the long exposures, and, in the case of the circular, to the possibility that the axis of rotation is pointed approximately toward the observer. It is apparent that in the latter case the spectrographic method cannot hope to succeed.

A number of the ring nebulæ give lines of such form as to suggest that the observed phenomena result from a combination of rotational motion and other type or types of motion. We are not prepared to interpret the phenomena, but in certain cases a motion of nebular materials toward the central nuclei of the objects is at least suggested, and for other nebulæ the complications seem to be due to absorption of the materials composing the outer strata of the nebular structures.

The observations indicate in general that the outer strata are rotating more slowly than the inner strata, both angularly and linearly. This is, in effect, a lagging behind of the outer strata.

Measures of the rotational velocity of a nebula enable us to draw some interesting conclusions concerning its probable mass. Assuming that a particle of material in a nebula at a given angular distance from the center is moving in obedience to the gravitational force of the central mass, in accordance with Newton's law, then, if the central mass is assumed to be equal to the mass of our Sun, we should find that the maximum position distances of the ten or twelve nebulæ whose observed motions are interpretable as rotations lie between 250 light-years and 5 light-years. Such small distances are improbable, in view of evidence of other kinds. If we assume that these nebulæ are at distances of 1000 light-years, which we think is a more probable order of distance, the minimum values of their masses, in terms of the Sun's mass, lie between 4 and 210.

As we have remarked earlier, it is difficult to avoid the conclusion that the so-called ring nebulæ, which are so plentiful amongst the planetaries, are in reality not ring forms in space, but ellipsoidal shells. If these forms are rotated about the minor axis of figure, which also seems highly probable, it is difficult to account for their apparent equilibrium under the usual rotational and gravitational forces; it would seem that the nebular materials in the polar regions—the regions at the extremities of the rotation axes—should be depressed toward the central nuclei. Are other forces, possibly including radiation pressure, involved?

Inasmuch as the observer will not in general be situated in the planes of the equators of rotation of the nebulæ, the observed rotational velocities must be smaller than their true values. On this account, the actual masses of the observed nebulæ should be greater than the minimum values assigned above. The effect of any radiation pressures would likewise make the deduced masses smaller than they are. The indications are that the nebulæ under consideration are capable of developing into something analogous to our solar system, but much more massive than is our solar system.

W. W. CAMPBELL,
November 20, 1916. J. H. MOORE.

RECENT IMPROVEMENTS AT THE LICK OBSERVATORY.

Minor injuries to a large section of the west outside wall of the main building resulting from the severe earthquake of July, 1911, came prominently to sight in the past winter, and repairs were necessary. Advantage was taken of the situation to combine improvements with repairs. The north room of the main building has up to the present time contained five astronomical clocks. These clocks were of the highest class obtainable at the time of their purchase, three decades ago, but they are now surpassed in excellence by modern clocks. Our chief dependence in recent years has been upon the Riefler constant-pressure clock, mounted on a stone pier within a separate masonry chamber constructed in the basement of the meridian circle house. We have this summer enclosed and given finish to a room of considerable size in that basement, with the Riefler clock chamber in one corner of the room. The Dent sidereal clock and the Frodsham mean-time clock have been moved from the old clock room to a suitable enclosing chamber in the new room. One Hohwü sidereal clock from the old clock room has been mounted in a new protecting case on one of the strong piers in the meridian observing room. The other Hohwü sidereal clock has been transferred from the old clock room to the observers' room at the Crossley dome. The Howard mean-time clock has been moved to a new protecting case near the intersection of the corridors of the main building, where it is in convenient position for members of the staff and community, and where the visiting public may compare their watches. The old clock room has been converted into an astronomer's office. The large office, known to all members of the staff, past and present, as the Assembly Room, has been divided into two offices. The north wing of the main building now contains four large offices, each with two windows. It has always been difficult to heat the old offices on windy days, as the rooms were sixteen feet from floor to ceiling. New ceilings have reduced the height to twelve feet. The switchboard which serves to connect clocks, chronometers, chronographs and observing rooms at the will of the observer, has been moved from the main corridor to a point in the meridian circle room immediately above the new clock room. A new stairway leads directly down from the main floor of the meridian circle house to the entrance door of the new clock room.

W. W. CAMPBELL.

Note on the Spectrum of the Nebula N. G. C. 7293.

In these PUBLICATIONS, **24**, 228, 1912, Dr. H. D. Curtis called attention to an interesting nebula, N. G. C. 7293 $(\alpha = 22^h\ 24.^m3;\ \delta = 21^\circ\ 21')$. The long-exposure photograph made with the Crossley reflector, and reproduced with Dr. Curtis's article, seems to indicate a helical or ring form for this object. Its extreme diameter, including the faint extensions, is about fifteen minutes of arc. It has therefore the largest angular diameter of any ring-form object known.

Considerable interest attaches to the spectral type of this nebula, on account of its great apparent size and regular form. Visual observations of its spectrum were recently made by us with a three-prism spectrograph mounted on the 36-inch refractor. With the slit placed upon the stronger northern edge of the nebula, the bright line of nebulium at 5007 A was easily seen, and we were able to glimpse the nebulium line at 4959 A. With the slit upon the opposite bright region (the southwest edge) the two nebulium lines were still visible, but very faint.

The spectrum of this nebula is then of the bright-line type characteristic of planetary nebulæ. It may be that N. G. C. 7293 is one of the nearer planetaries to our solar system.

W. W. CAMPBELL,
J. H. MOORE.

Mr. Ferdinand John Neubauer, A.B. 1910 and A.M. 1912 University of Oregon, at present Teaching Fellow in the Berkeley Astronomical Department, has been appointed University Fellow in the Lick Observatory for the second semester of the current year, January to July, 1917.

GENERAL NOTES.

The Diameter of the Pupil of the Eye.—An interesting note on this point is given by Mr. W. H. Steavenson in the *Journal of the British Astronomical Association* for June, 1916:

> "Nearly every textbook dealing with the practical side of astronomy contains the familiar statement that the lowest power which can usefully be employed on any telescope is one of five to each inch of aperture. This statement is, of course, based on the assumption that the average diameter of the human pupil is one-fifth of an inch. It is impossible to find out how the adoption of this value originated, but it was presumably the outcome of an inquiry addressed by some astronomer to one of his physiological friends. If this was so, it is somewhat unfortunate that the physiologist omitted to mention that the value given was only a *daylight* average. As such it is, no doubt, very fairly correct, but it obviously has no useful application to the astronomical telescope, which is used almost entirely at night. The question which really concerns the astronomer is: what is the average diameter of the pupil under ordinary observing conditions, *i. e.*, in semi-darkness?"

Mr. Steavenson, to test out this time-honored tradition, adopted the ingenious plan of taking flashlight photographs of several persons in a darkened room, allowing about ten minutes in each case for the pupil of the eye to adapt itself to the semi-darkness. The average pupillary diameter for five subjects was found to be just over one-third of an inch. Statements in nearly every astronomical textbook will have to be changed as the result of these simple experiments.

This improved value has a direct bearing upon the value of the lowest magnifying power which can be employed with a telescope. The emergent pencil of rays from an eyepiece must have a smaller diameter than that of the pupil, otherwise the full aperture of the lens is not utilized. It would seem then that the lowest practicable power is about three to each inch of aperture, a point of considerable importance in observing very faint objects or in searching for comets.

In this connection it is of interest to note that the Reverend John Michell, in a paper in the *Philosophical Transactions* for 1767, makes the statement: "for the pupil of the eye is not less than a third of an inch in diameter, in a clear starlight night, when there is no moon." Whether this anticipation of Steavenson's results was the result of experiments or merely a lucky guess on Michell's part can not be determined, as only the bare statement is given.

A Remarkable Aurora.—On the evening of August 26 an aurora of phenomenal brilliancy and magnitude was seen over all southern Canada and in the northern States. Observations have been reported from places in Nova Scotia and British Columbia, three thousand miles apart. The display reached its greatest beauty in parts of Canada, where it is described as filling the entire visible hemisphere of the sky. It does not appear to have been seen in California; should any observers in this latitude have noticed the phenomenon, they are invited to send brief notes of the display to Dr. C. A. Chant, University of Toronto, Toronto, Canada.

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC,

Held in the Rooms of the Society on October 7, 1916, at 12:15 p. m.

This was a special meeting, called by the President because of the failure of the regular Board Meeting in August, when the Society went to San Diego, and having for its special purpose the consideration of certain plans to establish a lecture course and to increase the membership of the Society.

There were present: President S. D. Townley and Directors Campbell, Cushing, Curtis, Leuschner, Markwart, Hodghead and Richardson. By special invitation there were also present the following non-official members of the Society: Dr. R. G. Aitken, Mr. J. Costa, Professor Geo. C. Edwards, Dr. Sturla Einarsson, Mr. J. D. Galloway, Mr. B. A. Baird and Mr. F. R. Ziel.

The following were elected members of the Society:

Prince Rohani Thirunal Raja,
Assistant Director and Astronomer,
Royal Observatory, Trivundrum,
Travancore, India.

Martinus Nijhoff,
S. Gravenhage, Netherlands.

R. E. Vandruff,
San Diego, California.

Mrs. Marie Caul Cox,
El Centro, Imperial County, California.

The President called for a report from the committee appointed at the meeting of January 29, 1916, to consider plans for increasing the membership of the Society. Dr. Aitken, the Chairman of the Committee, stated that the report he would submit was the result of numerous conferences with many active members of the Society, especially Messrs. Campbell, Curtis, Costa, Cushing and Richardson. He presented two definite recommendations, and after full discussion by all present these were embodied in two resolutions as expressing the sense of the meeting. The first resolution, moved by Director Leuschner, seconded by Director Cushing, and unanimously adopted was:

Resolved, That in order to stimulate interest in Astronomy, and in the work of the Astronomical Society of the Pacific, a series of lectures be given in San Francisco this winter, two before the Christmas holidays, and the others after, on dates other than those of the regular meetings of the Society; that provision be made to pay the expenses of lecturers, to secure a hall, lantern, and adequate advertising; that the first two lectures of this series be given by Dr. Campbell and that the others be given by competent speakers to be named later.

The President appointed a committee consisting of Aitken, Costa, Cushing and Richardson, to make arrangements for these lectures and properly advertise them. Incidentally, it was understood that expenses for these lectures were not to come from the regular funds of the Society, but that they were to be provided for from private subscriptions.

The second resolution, presented by Director Curtis and seconded by Director Markwart, and unanimously adopted was:

Resolved, That a committee of three be appointed by the President to prepare a personal letter of invitation to join the Society, and that said letter be sent to such persons as may be named by present members of the Society; that Dr. Campbell be made Chairman of this committee and one of the sponsors of the letter, and that all members of the Society be urged to send in a list of such names to the Secretary at an early date.

The President stated that he would name the two members to serve with Dr. Campbell on this committee at a later time.

Adjourned.

D. S. Richardson,
Secretary.

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC,

HELD IN THE ROOMS OF THE SOCIETY ON OCTOBER 28, 1916, AT 12:15 P. M.

There were present President Townley and Directors Cushing, Markwart, Leuschner, Burckhalter and Richardson.

The President announced that the reason for calling a special meeting of the Board was to take proper action in regard to a generous gift to the Society by Mr. Adolfo Stahl, for the maintenance of a course of popular lectures on astronomy.

After full discussion by the Board the following resolutions were introduced by Director Markwart, seconded by Director Leuschner, and unanimously adopted:

WHEREAS, A distinguished service has been rendered to the science of Astronomy, and to the Astronomical Society of the Pacific, by the liberal action of Mr. Adolfo Stahl, of San Francisco, in donating a generous sum of money to the Society for the maintenance of a course of popular lectures on astronomical subjects; therefore be it

Resolved, That the thanks of the Astronomical Society of the Pacific are due and are hereby gratefully extended to Mr. Stahl for his generous gift.

Resolved, That the fund so donated shall be known as THE ADOLFO STAHL LECTURE FUND of the Astronomical Society of the Pacific and that the course of lectures to be given thereunder shall be designated as THE ADOLFO STAHL LECTURE COURSE of said Society.

Resolved, That, in accordance with the provisions of Section I of Article II of the By-Laws of the Astronomical Society of the Pacific, Mr. Stahl be declared a PATRON thereof, and that he be elected to Life Membership in said Society with all the privileges attached thereto.

With a view to more fully outline the duties and powers of the Special Lecture Committee appointed at the Special Board Meeting of October 7, 1916, the following motion was made by Director Leuschner, seconded by Director Cushing, and, after discussion, carried:

Moved, That full power be conferred upon the Lecture Committee appointed at the Special Board Meeting of October 7, 1916, and consisting of Messrs. Aitken, Costa, Cushing and Richardson, to proceed with arrangements for a course of six lectures, as per plans already outlined, same to be given under the auspices of the Adolfo Stahl

Lecture Fund. The Committee shall have power to incur all necessary expenses, secure speakers and fix dates.

The following new members were elected:

Mr. Louis Rosenthal, of San Francisco.
Mr. Sam B. Stot, of San Francisco.
Mr. Arthur M. Brown, of San Francisco.
Mr. Cabell C. Kinney, of San Francisco.
Mr. Frank J. Devlin, of San Francisco.
Mr. Bertran E. Abrahamson, of San Francisco.

Adjourned.

D. S. RICHARDSON,
Secretary.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC,

HELD ON SATURDAY, NOVEMBER 25, 1916, AT 5:45 P. M.
AT STANFORD UNIVERSITY, CALIFORNIA.

This meeting was originally called for 2:00 P. M. of the same date, in the office of President Townley, on the campus of Stanford University, but was adjourned, for want of a quorum, until 5:45 P. M., when the Directors met at the Stanford Inn and held their session about a very daintily prepared dinner table, due to the art and thoughtfulness of the President.

There were present President Townley and Directors Campbell, Curtis, Cornish, Leuschner, Hodghead and Richardson.

Miss Rosa Isaac, of San Francisco, was elected as a student member of the Society.

A vote of thanks was extended to Mr. John Goss, of San Francisco, for the gift to the library of the Society of four volumes of *El Soliel.*

A communication from Mr. Adolfo Stahl was read by the Secretary, thanking the Board for the title of PATRON, recently conferred upon him, and for the honor of Life Membership.

A communication was read from Mr. Albert L. Barrows, Secretary of the Pacific Division of the American Association for the Advancement of Science, asking the sense of the Board as to an annual assessment of $5.00 upon each of the fourteen societies now affiliated with the Pacific Division. On motion of Director Leuschner, seconded by Director Campbell, the Affiliation Committee, consisting of Dr. Townley and Dr. Crawford, was instructed to reply to Secretary Barrows that the plan of levying an assessment as above noted had the approval of the Astronomical Society of the Pacific.

The following were appointed an Auditing Committee to examine, and report at the next annual meeting, upon the accounts of the Treasurer:

Charles S. Cushing, Chairman,
John D. Galloway,
Dr. Sturla Einarsson.

The Board then resolved itself into a Special Session to consider the award of the Bruce Gold Medal for the year 1917. Proxies from Director Cushing and Director Markwart were held by Directors Campbell and Richardson respectively.

Nominations were read from five of the six nominating observatories, Berlin alone not responding.

After a very full and candid discussion of the merits of the various names presented, the unanimous choice of the Board fell upon Professor E. E. Barnard, of the Yerkes Observatory.

Adjourned.

D. S. Richardson,
Secretary.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC

At Stanford University on November 25, 1916,
at 8:00 p. m.

By courtesy of the authorities of Leland Stanford Junior University, the regular meeting of the Society on this date was held in Room 100, known as the "Little Theater," on the inner quadrangle, near the President's office.

Dr. W. W. Campbell, Director of Lick Observatory, delivered an illustrated lecture on "*Comets.*" The lecture gave, in non-technical language, an account of the present state of our knowledge of these interesting bodies and was fully illustrated by lantern-slides.

Adjourned.

D. S. Richardson,
Secretary.

OFFICERS OF THE SOCIETY.

S. D. Townley	*President*
C. S. Cushing	*First Vice-President*
H. D. Curtis	*Second Vice-President*
A. H. Markwart	*Third Vice-President*
D. S. Richardson	*Secretary and Treasurer*

Board of Directors—Chas. Burckhalter, W. W. Campbell, F. V. Cornish, Wm. H. Crocker, H. D. Curtis, C. S. Cushing, B. L. Hodghead, A. O. Leuschner, A. H. Markwart, D. S. Richardson, S. D. Townley.

Publication Committee—R. G. Aitken, H. D. Curtis, H. Shapley.
Finance Committee—C. S. Cushing, W. H. Crocker, A. H. Markwart.
Library Committee—D. S. Richardson, F. V. Cornish, F. E. Brasch.

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